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Ligand Effects in the Rhodium(II) Catalysed Reactions of Diazoamides and Diazoimides

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Abstract: A range of substituted α-diazoamides **1-8** and diazoimides **9-12** was prepared from the corresponding amines or amides. Rhodium(II) catalysed decomposition of the diazoamides resulted in attack on the aromatic ring to give oxindoles or attack on the alkyl group to give either β-lactams or cycloheptapyrrolones. The chemoselectivity of the rhodium carbenoid intermediate was dependent on the metal ligands, fluorinated carboxamides strongly promoting attack on aromatic rings in preference to other processes. Decomposition of the diazoimides resulted in intramolecular attack on the carbonyl group to give an ylide which could be trapped inter- or intramolecularly. *X*-Ray crystal structures are reported for the diazo compounds **2** and **4**, the indoles **17** and **25**, the β-lactam **20**, the cycloheptapyrrolones **24** and **28**, the dimer **29** and the Pictet Spengler product **39**.

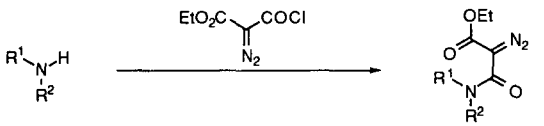
INTRODUCTION

The rhodium(II) catalysed decomposition of α-diazocarbonyl compounds leads to a transient metal carbenoid which can subsequently undergo a range of synthetically useful reactions.[1-6] A number of studies have shown that, despite their high reactivity, rhodium carbenoid intermediates are often highly chemoselective when two or more reaction pathways are open to them.[7] Site selectivity has been found to depend not only on the type of α-diazocarbonyl utilized, but is also governed by steric,[8-11] conformational[12] as well as electronic factors.[13-16] The earlier studies have revealed some interesting ligand effects, and it is now established that carboxylate and carboxamide ligands in rhodium(II) catalysts can effectively control chemoselectivity in competitive carbenoid transformations of α-diazocarbonyl compounds.[17] We have recently reported that the rhodium(II) catalysed decomposition of *N*-aryldiazoamides is subject to dramatic ligand effects.[18] We now describe the results of a more detailed study of substituent effects in the diazocarbonyl substrate, together with ligand effects in the rhodium(II) catalyst.

RESULTS AND DISCUSSION

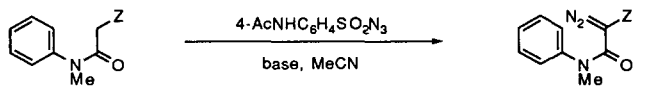
Preparation of α-Diazocarbonyl Compounds

The α-diazocarbonyl compounds chosen for study were the diazoamides **1** - **8** and the diazoimides **9** - **12**. Diazoamides **1** - **6** were readily prepared by acylation of the corresponding amine with ethyl diazomalonyl chloride (Scheme 1).[19] In cases where the starting amine R^1R^2NH was not commercially available, these were prepared by reduction of the corresponding amide (see Experimental Section). The cyano and sulfonyl diazo compounds were prepared by diazo transfer to the corresponding α-substituted *N*-methyl acetanilides **13** (Scheme 2). Diazoamides **2** and **4** were both highly crystalline, and were therefore subjected to *X*-ray crystallographic analysis.[20] The structures (Figures 1 and 2) show that the diazo group adopts a conformation in which it is *syn* to the amide carbonyl and *anti* to the ester carbonyl. This conformation, which has been noted previously in the crystal structure of a related diazoamide,[18] has the diazo carbon pointing toward the *N*-aryl group in the diazoamide.



1 $R^1 = R^2 = Ph$
2 $R^1 = Ph$, $R^2 = CH_2)_2$
3 $R^1 = 4\text{-}MeOC_6H_4$, $R^2 = PhCH_2$
4 $R^1 = 3\text{-}MeOC_6H_4$, $R^2 = PhCH_2$
5 $R^1 = Ph$, $R^2 = 4\text{-}MeOC_6H_4CH_2$
6 $R^1 = R^2 = PhCH_2$

Scheme 1

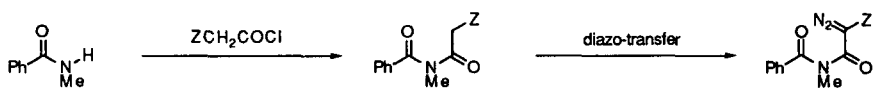


13a Z = CN
13b Z = SO_2Ph

7 Z = CN
8 Z = SO_2Ph

Scheme 2

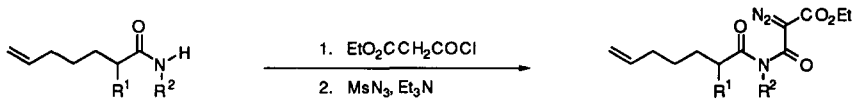
Diazoimides **9** and **10** were conveniently prepared from *N*-methylbenzamide by acylation and diazotransfer as shown in Scheme 3. Diazosulfone **10** could not be obtained pure as it rapidly decomposed. It was therefore generated and used immediately. Similar treatment of the 6-heptenoic acid amides **15** (see Experimental Section) gave the diazoimides **11** and **12** (Scheme 4).



14a Z = CO_2Me
14b Z = SO_2Ph

9 Z = CO_2Me
10 Z = SO_2Ph

Scheme 3



15a $R^1 = ArCH_2CH_2$, $R^2 = Me$
15b $R^1 = H$, $R^2 = ArCH_2CH_2$

11 $R^1 = ArCH_2CH_2$, $R^2 = Me$
12 $R^1 = H$, $R^2 = ArCH_2CH_2$

Scheme 4 (Ar = 3,4-dimethoxyphenyl)

Figure 1. *X*-ray crystal structure of bis-diazoamide **2**.

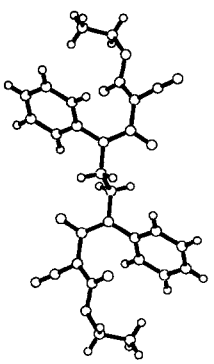
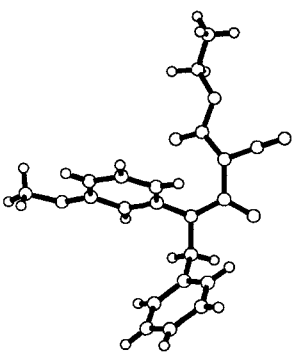


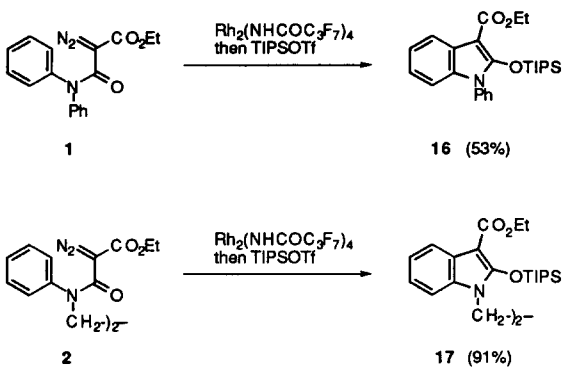
Figure 2. *X*-ray crystal structure of diazoamide **4**.



Rhodium(II) Catalysed Decomposition of Diazoamides 1 - 8

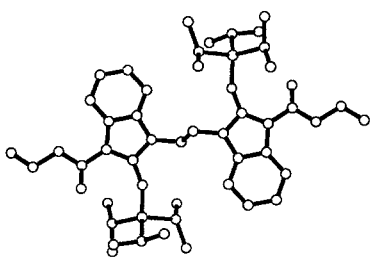
The simple diazoamide **1** derived from diphenylamine was decomposed in the presence of rhodium(II) perfluorobutyramide, and gave as expected the corresponding oxindole by intramolecular attack of the carbenoid on the aromatic ring. In this, and other examples, the crude mixture was treated with tri-isopropyl-silyl trifluoromethanesulfonate, TIPSOTf, and the product was therefore isolated as the corresponding 2-tri-isopropylsiloxyindole **16** (Scheme 5). Similar treatment of the *bis*-diazoamide **2** gave the 1,2-*bis*-indolyl-ethane **17** in excellent yield (Scheme 5), the structure of which was confirmed by *X*-ray crystallography (Figure 3).[20]

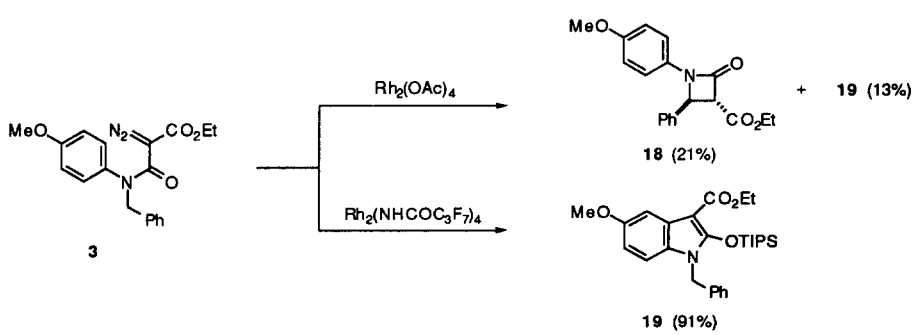
On the basis of our previous results,[18] rhodium(II) catalysed decomposition of the *N*-aryl-*N*-benzyldiazoamides **3** and **4** was expected to give β-lactams by intramolecular C-H insertion into the benzylic CH_2 group, and/or oxindoles by intramolecular attack on the aromatic ring. This indeed proved to be the case, and the reaction exhibited similar ligand effects to those observed previously. Thus, rhodium(II) acetate catalysed decomposition of diazoamide **3** gave the 1,4-diarylazetidinone **18** (21%) together with the *O*-silyl oxindole **19** (13%) (Scheme 6); these were the only products isolated from a complex reaction mixture. However, on changing to rhodium(II) perfluorobutyramide as catalyst, a much cleaner reaction was observed, and the only product isolated after silylation was the indole **19** in excellent yield (91%) (Scheme 6).



Scheme 5

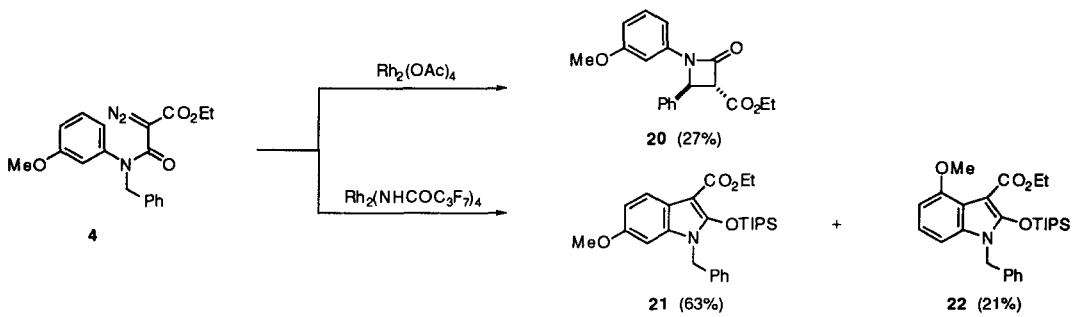
Figure 3. *X*-ray crystal structure of bisindole **17**.





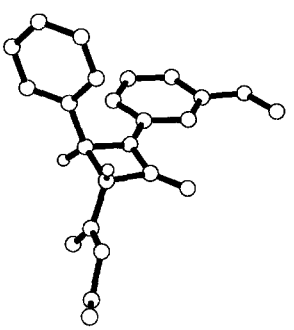
Scheme 6

The rhodium(II) catalysed decomposition of diazoamide **4** proceeded similarly. Rhodium(II) acetate as catalyst gave the β-lactam **20** (27%) as part of a complex reaction mixture. Use of rhodium(II) perfluorobutyramide however gave, after silylation, a high yield of the 6-methoxy- and 4-methoxy indoles **21** and **22**. Not surprisingly, cyclisation *para-* to the methoxy group was favoured, the ratio of **21** to **22** being 3:1 (Scheme 7). The stereochemistry of the β-lactams **18** and **20** was assigned as *trans* on the basis of their 1-H NMR spectra (H3-H4, J = 2.60 and 2.65 Hz respectively), and in the case of **20**, was confirmed by *X*-ray crystallography (Figure 4). Hence in neither case (**3** or **4**) did the electron releasing group in the *N*-aryl ring divert the rhodium(II) acetate generated carbenoid away from C-H insertion reactions in favour of 'electrophilic' attack on the aromatic ring to a significant extent.



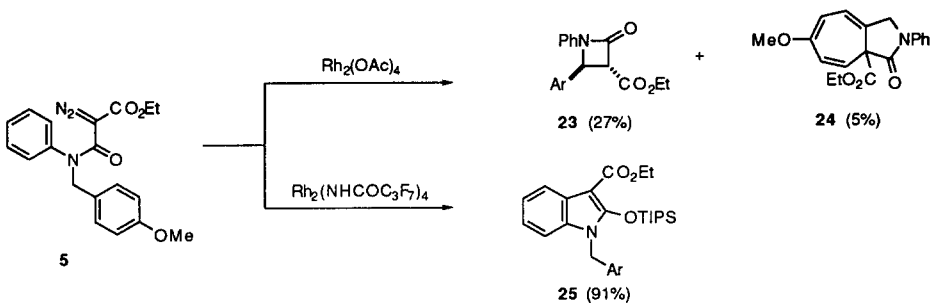
Scheme 7

Figure 4. *X*-ray crystal structure of β-lactam **20**.



Rhodium(II) catalysed decomposition of the diazoamide **5** was studied in order to investigate the effect of an electron releasing group in the *N*-benzyl substituent. The rhodium(II) acetate catalysed decomposition of **5** gave the *trans* β-lactam **23** in 27% yield together with a minor product identified as the

cycloheptapyrrolone **24** (5%) (Scheme 8). This latter product is presumably formed by intramolecular attack on the aromatic ring of the 4-methoxybenzyl group followed by pericyclic rearrangement of the norcaradiene intermediate.[21] Hence the introduction of the methoxy group into the benzyl substituent does open up a new reaction pathway. Rhodium(II) perfluorobutyramide catalysed decomposition of **5** proceeded as expected to give, after silylation, the indole **25** in excellent yield (Scheme 8). The structure of the cycloheptapyrrolone **24** was confirmed by *X*-ray crystallography (Figure 5), as was that of the indole **25** (Figure 6).[20]



Scheme 8 (Ar = 4-methoxyphenyl)

Figure 5. *X*-ray crystal structure of cycloheptapyrrolone **24**.

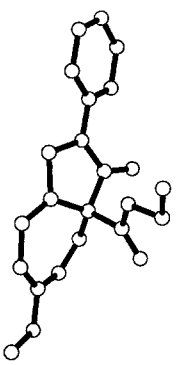
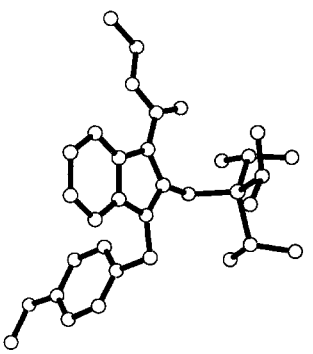
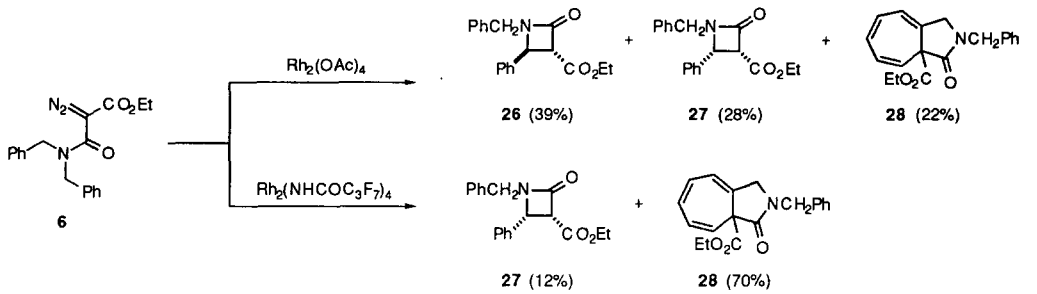


Figure 6. *X*-ray crystal structure of indole **25**.



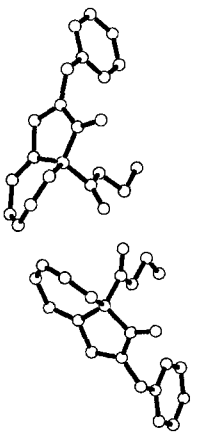
The isolation of the cycloheptapyrrolone **24**, albeit in poor yield, prompted us to investigate the decomposition of the diazoamide **6** which might result in higher yields of such cycloheptatrienes since one reaction pathway (oxindole formation) is precluded. In the event, this proved to be the case, and the rhodium(II) acetate catalysed decomposition of **6** gave the expected *trans* β-lactam **26** (39%) (H3-H4, $J = 2.2$

Hz), together with its *cis*-isomer **27** (28%) (H3-H4, J = 6.0 Hz), and the cycloheptapyrrolone **28** (22%) (Scheme 9). The reason for formation of the *cis* β-lactam in addition to the *trans*- isomer in this particular case is not clear. As expected, use of the perfluorobutyramide ligand favoured attack on the aromatic ring and gave the cycloheptapyrrolone **28** in high yield together with some *cis* β-lactam **27** (Scheme 9). The structure of the cycloheptapyrrolone **28** was confirmed by X-ray crystallography (Figure 7).[20]



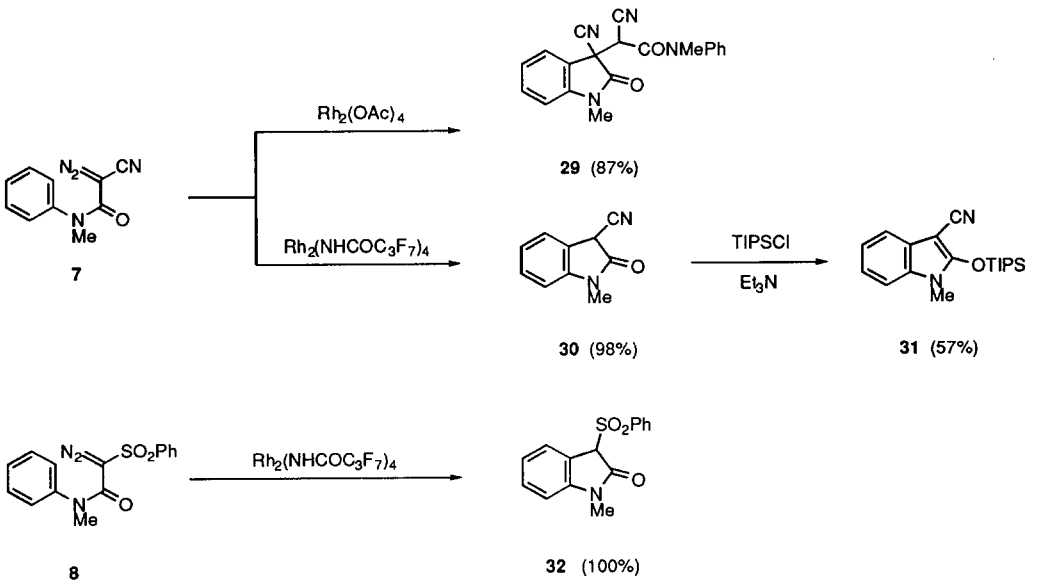
Scheme 9

Figure 7. X-ray crystal structure of cycloheptapyrrolone **28** (2 crystallographically independent molecules).



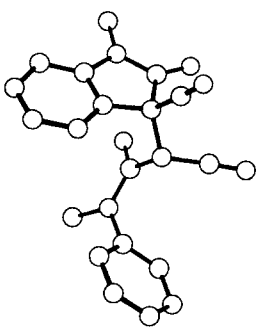
Finally the effect of the electron withdrawing group on diazoamide decomposition was investigated with diazonitrile **7** and diazosulfone **8**. Rhodium(II) perfluorobutyramide catalysed decomposition of both diazoamides **7** and **8** resulted in formation of the corresponding oxindoles **30** (98% crude) and **32** (100%); oxindole **30** was purified by conversion into the 2-tri-isopropylsiloxyindole **31** (Scheme 10). The oxindole **32** was also formed from the diazosulfone **8** on treatment with rhodium(II) acetate. However use of this catalyst with diazonitrile **7** resulted in the formation of an unusual dimer **29** in 87% yield as a 1:1-mixture of diastereomers.

The structure of the less soluble diastereomer **29a** was confirmed by *X*-ray crystallography (Figure 8).[20] Presumably dimer **29** arises by an intermolecular C-H insertion reaction of the carbenoid into the 3-position of the oxindole **30**.



Scheme 10

Figure 8. *X*-ray crystal structure of dimer **29**

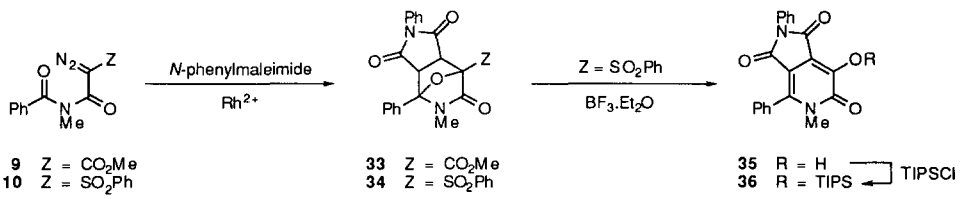


Rhodium(II) Catalysed Decomposition of Diazoimides 9 - 12.

On the basis of previous results, the rhodium catalysed decomposition of diazoimides was expected to result in intramolecular capture of the carbenoid by the carbonyl oxygen with formation of a 1,3-oxazolium-4-oxide (isomünchnone). This type of mesoionic betaine corresponds to the cyclic equivalent of a carbonyl ylide

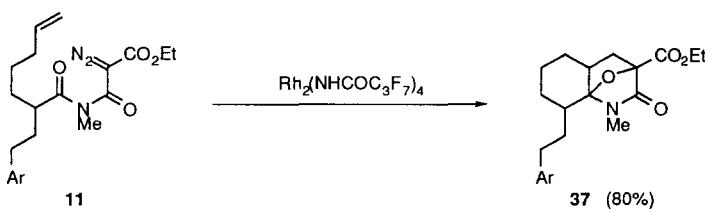
and readily undergoes 1,3-dipolar cycloaddition.[22-26] Formation of the isomünchnone ring can be rationalized by initial generation of a metallo-carbenoid species which is then followed by intramolecular cyclization onto the neighboring carbonyl oxygen to form the dipole.[4] The resulting isomünchnone can be trapped with dipolarophiles to give bimolecular cycloadducts in high yield.[27] We were also able to show that the dipolar-cycloaddition of isomünchnones with alkenes occurs intramolecularly and that the overall reaction represents an efficient way to synthesize complex polyheterocyclic ring systems.[26,28]

Hence the diazoimides **9** and **10** were treated with a range of rhodium(II) catalysts in the presence of *N*-phenylmaleimide as the dipolarophile. Rhodium(II) perfluorobutyrate proved to be the best catalyst for diazoimide **9**, and gave cycloadduct **33** in good yield (Scheme 11). Rhodium(II) perfluorobutyramide, however, gave a poorer yield of cycloadduct **33** (48%), whilst rhodium(II) acetate proved to be a very ineffective catalyst with only 10% conversion after 72 hours. Although the sulfonyldiazoimide **10** could not be obtained completely pure (see earlier), its rhodium(II) acetate catalysed reaction resulted in isomünchnone formation which was followed by trapping with *N*-phenyl maleimide to give cycloadduct **34** in 49% yield (from **14b**). Attempted dipole generation with rhodium(II) perfluorobutyramide gave **34** in only 7% yield, whereas the perfluorobutyrate catalyst afforded no cycloadduct. Cycloadduct **34** underwent facile ring opening and elimination in the presence of boron trifluoride etherate to give the 3-hydroxy-2-pyridone **35** isolated as its tri-isopropylsilyl ether **36** (Scheme 11).



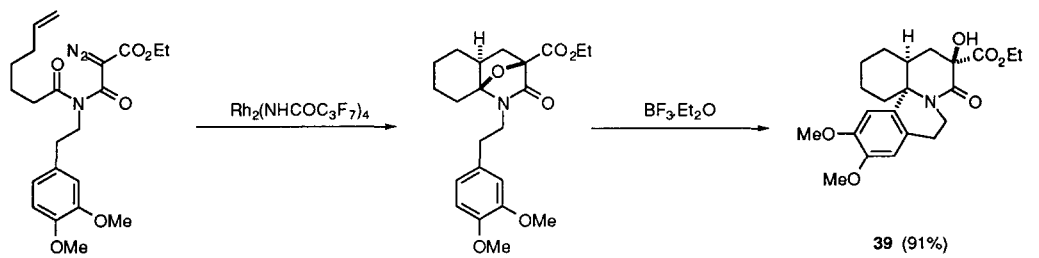
Scheme 11

Diazoimides **11** and **12** both contain an intramolecular trap for the mesoionic dipole. The cycloaddition behavior of **11** was examined using three rhodium catalysts (perfluorobutyrate, perfluorobutyramide, acetate). While all three catalysts gave the intramolecular cycloadduct **37** as the major product (Scheme 12), rhodium(II) acetate was the least effective. The variation in reactivity (yield) presumably reflects the differences in electrophilicity between the various rhodium carbenoid intermediates.



Scheme 12 (Ar = 3,4-dimethoxyphenyl)

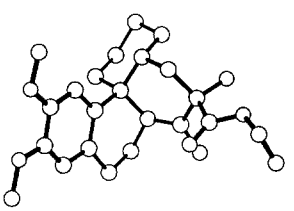
The reaction of diazoimide **12** with rhodium(II) perfluorobutyrate gave cycloadduct **38** in quantitative yield. In this case there was no significant ligand effect, although use of rhodium(II) acetate resulted in a poorer (76%) yield of the cycloadduct. Treatment of the cycloadduct with boron trifluoride etherate resulted in a Pictet Spengler type cyclisation giving the tetrahydroisoquinoline **39** in 91% yield (Scheme 13), the structure of which was confirmed by *X*-ray crystallography (Figure 9).[20]



12 **38** (100%) **39** (91%)

Scheme 13

Figure 9. *X*-ray crystal structure of Pictet-Spengler product **39**.



Conclusions

The rhodium catalysed decomposition of diazoamides is subject to significant ligand effects. Fluorinated carboxamide ligands promote intramolecular attack on aromatic rings to give, depending on the substrate, oxindoles or cycloheptapyrrolones. Rhodium(II) acetate on the other hand promotes C-H insertion reactions. Diazoimides are less susceptible to ligand effects on rhodium catalysed decomposition. Intramolecular carbonyl ylide formation is favoured by all catalysts.

EXPERIMENTAL SECTION

For general experimental points, see references 7d and 18.

PREPARATION OF DIAZOCARBONYL COMPOUNDS

General Procedures

Preparation of substituted benzanilides

A solution of the aroyl chloride (1.0 eq) in CH_2Cl_2 was added slowly to a stirred solution of the aniline (1.0 eq) and triethylamine (1.1 eq) in CH_2Cl_2. Stirring was maintained for 18 h at room temperature. The resulting mixture was washed with dilute HCl (2M), water and saturated brine then dried over Na_2SO_4. Concentration under reduced pressure yielded an off-white solid which could be recrystallised from ethanol to give the desired product as a crystalline solid.

Preparation of substituted N-Benzylamines

A solution of substituted benzanilide (1.0 eq) in dry THF was slowly added to a stirred suspension of $LiAlH_4$ (1.1 eq) in dry THF and the mixture refluxed for 18 h. The mixture was cooled to room temperature and then carefully quenched with water (0.07 mL per mmol of $LiAlH_4$). With stirring, aqueous NaOH (10%; 0.085 mL per mmol of $LiAlH_4$) and flash grade silica (0.14 g per mmol of $LiAlH_4$) were added. The resulting suspension was filtered through a pad of Celite and the filtrate concentrated under reduced pressure to yield the crude product which could be further purified by distillation or by flash silica gel chromatography and recrystallisation.

Preparation of substituted N-Benzyl-N-phenyl-2-diazomalonamic Acid Ethyl Esters

A stirred solution of the appropriate amine (1.0 eq) in CH_2Cl_2 was treated with triethylamine (2.0 eq) and ethyl 2-diazomalonyl chloride (1.0 eq). The solution was stirred at room temperature for 3-18 h then washed with dilute HCl (2M), water and saturated brine. The resulting solution was dried over Na_2SO_4 and concentrated under reduced pressure to yield the crude product which could be purified by flash silica gel chromatography and recrystallisation.

2-Diazo-N,N-diphenylmalonamic Acid Ethyl Ester 1

A solution of diphenylamine (0.500 g, 2.95 mmol) in CH_2Cl_2 (33 mL) was treated with triethylamine (0.82 mL, 5.90 mmol) and ethyl 2-diazomalonyl chloride (0.522 g, 2.95 mmol) and the mixture stirred at room temperature for 120 h. The resulting solution was preadsorbed on silica and subjected to flash silica gel chromatography (3:1 light petroleum:diethyl ether) to give recovered diphenylamine (0.272 g, 54%) and the *title compound* **1** (0.314 g, 34%) as a yellow oil; (Found: MH^+, 310.1192. $C_{17}H_{16}N_3O_3$ requires 310.1192); ν_{max}(neat)/cm^{-1} 2125, 1722, 1644, 1492, and 1345; δ_H (250 MHz; $CDCl_3$) 1.13 (3H, t, *J* 7.2 Hz), 4.02 (2H, q, *J* 7.2 Hz), 7.27-7.14 (6H, m), and 7.39-7.28 (4H, m); δ_C (100.6 MHz; $CDCl_3$) 14.21, 61.50, 126.63, 126.75, 129.23, 143.26, 161.48, and 161.88; *m/z* 310 (MH^+, 24%), 284 (39), 170 (100), and 52 (87).

Bis-diazocarbonyl compound 2

A solution of 1,2-dianilinoethane (0.50 g, 2.36 mmol) and triethylamine (1.31 mL, 9.42 mmol) was treated with ethyl 2-diazomalonyl chloride (0.83 g, 4.70 mmol) and the mixture stirred at room temperature for 5 h. The solution was then preadsorbed on silica and subjected to flash silica gel chromatography (2:1 light petroleum:diethyl ether then diethyl ether then CH_2Cl_2) to give the *bis-diazo compound* **2** (0.692 g, 60%), m.p. >125°C (decomp.)(from ethyl acetate/ethanol); (Found: MH^+, 493.1836. $C_{24}H_{25}N_6O_6$ requires 493.1836); $\nu_{max}(CH_2Cl_2)/cm^{-1}$ 2121, 1724, 1306 and 1118; δ_H (250 MHz; $CDCl_3$) 1.11 (6H, t, *J* 7.1 Hz), 3.99 (4H, q, *J* 7.1 Hz), 4.07 (4H, s), and 7.38-7.08 (10H, m); δ_C (100.6 MHz; $CDCl_3$) 13.95, 47.63, 60.01, 65.18, 124.77, 125.70, 128.13, 141.14, 159.73, and 160.40; *m/z* 493 (MH^+, 1%), 441 (7), 327 (15), 208 (25), 94 (29), and 52 (100).

N-Benzyl-2-diazo-N-(4-methoxyphenyl)malonamic Acid Ethyl Ester 3

Benzoyl chloride (1.43 g, 10.2 mmol) was condensed with *p*-anisidine (1.255 g, 10.2 mmol) in the standard manner to yield *N*-(4-methoxyphenyl)benzamide (1.63 g, 71%) as colourless plates after recrystallisation from ethanol, m.p. 165-166°C (lit.,[29] m.p. 157-158°C); (Found: M^+, 227.0946. Calc. for $C_{14}H_{13}NO_2$ 227.0946); $\nu_{max}(CH_2Cl_2)/cm^{-1}$ 3425, 1673, 1513, and 1248; δ_H (250 MHz; $CDCl_3$ + DMSO d_6) 2.68 (3H, s), 6.53 (2H, d, *J* 8.8 Hz), 7.20-7.08 (3H, m), 7.33 (2H, d, *J* 8.8 Hz), 7.61 (2H, d, *J* 7.8 Hz), and 9.35 (1H, brs); δ_C (62.9 MHz; $CDCl_3$ + DMSO d_6) 55.10, 113.51, 122.06, 127.36, 127.97, 130.98, 131.87, 135.14, 155.77, and 165.71; *m/z* 227 (M^+, 27%), 105 (100), 77 (74), and 51 (28).

N-(4-Methoxyphenyl)benzamide (1.60 g, 7.1 mmol) was reduced with $LiAlH_4$ (0.27 g, 7.1 mmol) in the standard manner to give essentially pure *N-benzyl-4-methoxyaniline* which could be taken forward to the next step without further purification, m.p. 49-51°C (light petroleum/diethyl ether); (Found: M^+, 213.1154. $C_{14}H_{15}NO$ requires 213.1154); $\nu_{max}(CH_2Cl_2)/cm^{-1}$ 3436, 1514, 1235, and 822; δ_H (250 MHz; $CDCl_3$) 3.76 (3H, s), 4.30 (2H, s), 6.66-6.58 (2H, m), 6.83-6.76 (2H, m), and 7.40-7.25 (5H, m); δ_C (62.9 MHz; $CDCl_3$) 49.19, 55.75, 114.04, 114.85, 127.10, 127.48, 128.34, 128.52, 139.63, and 142.39; *m/z* 213 (M^+, 46%), 122 (67), 91 (100), and 65 (23).

N-Benzyl-4-methoxyaniline (3.495 g, 6.54 mmol) was condensed with ethyl 2-diazomalonyl chloride (1.145 g, 6.54 mmol) in the standard manner to give the *title compound* **3** (2.157 g, 93% over 2 steps) as a yellow oil; (Found: M^+, 353.1376. $C_{19}H_{19}N_3O_4$ requires 353.1389); $\nu_{max}(neat)/cm^{-1}$ 2982, 2839, 2119, 1723, 1633, 1512, and 1298; δ_H (250 MHz; $CDCl_3$) 1.16 (3H, t, *J* 7.1 Hz), 3.78 (3H, s), 4.07 (2H, q, *J* 7.1 Hz), 4.94 (2H, s), 6.86-6.76 (2H, m), 7.01-6.94 (2H, m), and 7.28-7.20 (5H, m); δ_C (100.6 MHz; $CDCl_3$) 14.18, 54.29, 55.33, 61.27, 114.35, 127.38, 128.02, 128.34, 128.52, 134.87, 136.86, 158.41, 160.80 and 162.01; *m/z* 353 (M^+), 325 (M^+-N_2, 8%), 91 (100), and 28 (57).

N-Benzyl-2-diazo-N-(3-methoxyphenyl)malonamic Acid Ethyl Ester 4

N-(3-Methoxyphenyl)benzamide (6.57 g, 71%) was prepared by the condensation of benzoyl chloride (5.71 g, 40.6 mmol) and *m*-anisidine (5.00 g, 40.6 mmol) in the standard manner and was isolated, after recrystallisation from ethanol, as fine crystals, m.p. 116°C (lit.,[30] m.p. 112°C); (Found: M^+, 227.0945. Calc. for $C_{14}H_{13}NO_2$ 227.0946); ν_{max} $(CH_2Cl_2)/cm^{-1}$ 3432, 1680, and 1529; δ_H (400 MHz; $CDCl_3$) 3.80 (3H, s), 6.72-6.67 (1H, m), 7.13-7.09 (1H, m), 7.25 (1H, t, *J* 8.1 Hz), 7.55-7.41 (4H, m), 7.86-7.82 (2H, m) and 8.01

(1H, brs); δ_C (100.6 MHz; $CDCl_3$) 55.3, 205.8, 110.5, 112.35, 127.0, 128.8, 129.7, 131.8, 134.9, 139.2, 160.2, and 165.9; *m/z* 227 (M^+, 29%), 205 (100), 77 (47), 28 (28).

N-(3-Methoxyphenyl)benzamide (4.00 g, 17.61 mmol) was reduced with $LiAlH_4$ (0.668 g, 17.61 mmol) in the standard manner. Distillation of the crude product under reduced pressure yielded *N*-benzyl-3-methoxyaniline (3.447 g, 92%) as a viscous yellow oil, b.p. 150°C at 0.8 mmHg (lit.,[31] b.p. 226-227°C at 127 mmHg); ν_{max} (neat)/cm^{-1} 3029, 1497, and 1162; δ_H (250 MHz; $CDCl_3$) 3.72 (3H, s), 4.01 (1H, brs), 4.29 (2H, s), 6.30-6.15 (3H, m), 7.06 (1H, t, *J* 8.1 Hz), and 7.38-7.20 (5H, m).

N-Benzyl-3-methoxyaniline (1.25 g, 5.87 mmol) was condensed with ethyl 2-diazomalonyl chloride (1.0359, 5.87 mmol) in the standard manner to yield the *title compound* **4** (1.549 g, 75%) as pale yellow crystals (from diethyl ether/ethanol), m.p. 75-76°C; (Found: C, 64.60; H, 5.27; N, 11.72. $C_{19}H_{19}N_3O_4$ requires C, 64.58; H, 5.42; N, 11.89%); ν_{max} (CH_2Cl_2)/cm^{-1} 2123, 1722, and 1602; δ_H (250 MHz; $CDCl_3$) 1.15 (3H, t, *J* 7.1 Hz), 3.72 (3H, s), 4.06 (2H, q, *J* 7.1 Hz), 4.99 (2H, s), 6.79-6.60 (3H, m), and 7.29-7.15 (6H, m); δ_C (62.9 MHz; $CDCl_3$) 14.15, 54.2, 55.3, 61.3, 112.25, 112-3, 118.6, 127.4, 128.2, 128.4, 129.9, 136.9, 143.6, 160.1, 160.9, and 161.9; *m/z* 325 ($M^+ - N_2$, 20%), 279 (14), 252 (37), and 91 (100).

2-Diazo-N-(4-methoxybenzyl)-N-phenylmalonamic Acid Ethyl Ester 5

Commercially available *N*-phenyl-4-methoxybenzylamine (0.285 g, 1.34 mmol) was condensed with ethyl 2-diazomalonyl chloride in the standard manner to yield the *title compound* **5** (0.44 g, 93%) as a viscous yellow oil; (Found: MH^+, 354.1454. $C_{19}H_{20}N_3O_4$ requires 354.1454); ν_{max} (neat)/cm^{-1} 2982, 2937, 2123, 1723 and 1683; δ_H (250 MHz; $CDCl_3$) 1.12 (3H, t, *J* 7.1 Hz), 4.93 (3H, s), 6.82-6.75 (2H, m), and 7.31-7.13 (7H, m); δ_C (100.6 MHz; $CDCl_3$) 14.2, 53.7, 55.2, 61.3, 113.7, 126.6, 127.0, 129.0, 129.2, 129.8, 142.4, 158.9, 160.9 and 161.8; *m/z* 325 (M^+-N_2), 121 (100%), 77 (18), 28 (26).

N,N-Dibenzyl-2-diazomalonamic Acid Ethyl Ester 6

A solution of dibenzylamine (0.250 g, 1.26 mmol, 0.244 mL) in CH_2Cl_2 (15 mL) was treated with triethylamine (0.353 mL, 2.53 mmol) and ethyl 2-diazomalonyl chloride (0.224 g, 1.26 mmol) and the resulting mixture stirred at room temperature for 18 h; it was then washed with HCl (2M; 20 mL), water (20 mL), saturated brine (20 mL) and dried over Na_2SO_4. Preadsorption onto silica followed by flash silica gel chromatography yielded the *title compound* **6** (0.414 g, 97%) as a light yellow oil; (Found: MH^+, 338.1505. $C_{19}H_{20}N_3O_3$ requires 338.1505; ν_{max} (neat)/cm^{-1} 2129, 1707, 1625, 1419, and 1293; δ_H (250 MHz; $CDCl_3$) 1.28 (3H, t, *J* 7.1 Hz), 4.26 (2H, q, *J* 7.1 Hz), 4.51 (4H, s), and 7.38-7.12 (10H, m); δ_C (100.6 MHz; $CDCl_3$) 14.40, 50.40, 61.54, 66.89, 127.62, 127.62, 127.84, 128.70, 136.32, 162.41, and 162.50; *m/z* 338 (MH^+, 100%), 327 (56), and 196 (82).

2-Cyano-2-diazo-N-methyl-N-phenylacetamide 7

To a solution containing cyanoacetic acid (3.10 g, 36.4 mmol) in benzene (35 mL) at 0°C was added oxalyl chloride (9.52 mL, 109 mmol) which contained 1 drop of DMF and the mixture was allowed to stir at room temperature for 3 h. The mixture was concentrated under reduced pressure, dissolved in benzene (15 mL), and cannulated into a solution of of freshly distilled *N*-methylaniline (3.0 mL, 27.9 mmol) in benzene (30 mL). After being heated for 6 h at reflux, the mixture was concentrated under reduced pressure, taken up in CH_2Cl_2 and washed once with a saturated $NaHCO_3$ solution and once with brine. The combined organic

extracts were dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was subjected to flash silica gel chromatography to give 2-cyano-*N*-methyl-*N*-phenylacetamide **13a** (5.01 g, 79%) as a colourless solid, m.p. 67-68°C; ν_{max} (neat)/cm^{-1} 2257, 1666, and 1389; δ_H (300 MHz; $CDCl_3$) 3.21 (2H, s), 3.30 (3H, s), 7.20-7.23 (2H, m), and 7.43-7.48 (3H, m); δ_C (75 MHz; $CDCl_3$) 25.2, 37.6, 114.1, 126.8, 128.7, 130.2, 142.1, and 161.6.

To a solution containing **13a** (1.0 g, 5.73 mmol) in acetonitrile (35 mL) was added 4-acetamidobenzenesulfonyl azide (1.65 g, 6.89 mmol). The solution was cooled to 0°C, triethylamine (1.9 mL, 13.8 mmol) was added dropwise, and the solution was allowed to warm to room temperature over a 3 h period. The solvent was removed under reduced pressure and the residue was taken up in CH_2Cl_2 and filtered through a short silica plug to give the *diazo compound* **7** (0.57 g, 50%) as a yellow oil; (Found: M$^+$, 200.0699. $C_{10}H_8N_4O$ requires 200.0698); ν_{max} (neat)/cm^{-1} 2212, 2133, and 1639; δ_H (300 MHz; $CDCl_3$) 3.35 (3H, s), 7.23-7.25 (2H, m), and 7.41-7.45 (3H, m); δ_C (75 MHz; $CDCl_3$) 39.2, 42.9, 107.4, 127.9, 129.5, 130.2, 141.5, and 151.2.

2-Benzenesulfonyl-2-diazo-N-methyl-N-phenylacetamide 8

To a solution of phenylsulfonylacetic acid[32] (7.28 g, 36.4 mmol) in benzene (35 mL) was added oxalyl chloride (9.52 mL, 109 mmol) which contained 2 drops of DMF. This solution was allowed to stir for 2 h at room temperature after which time the excess oxalyl chloride was removed under reduced pressure. The crude acid chloride was taken up in benzene (20 mL) and was cannulated into a solution of *N*-methylaniline (3 g, 28.0 mmol) in benzene (20 mL) and heated at reflux for 8 h. The reaction mixture was concentrated under reduced pressure, taken up in CH_2Cl_2, washed once with a saturated $NaHCO_3$ solution, and then once with brine. The combined organic extracts were dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was subjected to flash silica gel chromatography to give 2-benzenesulfonyl-*N*-methyl-*N*-phenylacetamide **13b** (7.08 g, 87%) as a colourless solid, m.p. 118-119°C; ν_{max} (neat)/cm^{-1} 1658, 1314, and 1143; δ_H (300 MHz; $CDCl_3$) 3.26 (3H, s), 4.00 (2H, s), 7.19 (2H, d, *J* 8.1 Hz), 7.41-7.45 (3H, m), 7.55-7.66 (3H, m), and 7.92 (2H, d, *J* 8.1 Hz); δ_C (75 MHz; $CDCl_3$) 37.5, 58.8, 127.2, 128.5, 128.8, 130.0, 133.8, 139.4, 142.4, and 161.1.

To a solution containing **13b** (1.0 g, 3.46 mmol) in acetonitrile (35 mL) was added 4-acetamidobenzenesulfonyl azide (0.99 g, 4.14 mmol) and the solution was cooled to 0°C. DBU (0.58 mL, 3.5 mmol) was added dropwise and the solution was allowed to warm to room temperature over a period of 3 h. The solvent was removed under reduced pressure, the residue was taken up in CH_2Cl_2 and filtered through a short silica plug to give the diazo compound **8** (0.66 g, 61%) as a yellow oil which was resubjected to flash silica gel chromatography to afford of the pure *diazo compound* **8** (0.38 g, 34%) as bright yellow needles, m.p. 108-109°C; (Found: C, 57.21; H, 4.19; N, 13.39. $C_{15}H_{13}N_3O_3S$ requires C, 57.13; H, 4.16; N, 13.33%); ν_{max} (neat)/cm^{-1} 2850, 2122, and 1595; δ_H (300 MHz; $CDCl_3$) 3.24 (3H, s), 7.20 (2H, d, *J* 8.1 Hz), 7.38-7.46 (3H, m), 7.53-7.62 (3H, m), and 7.91 (2H, d, *J* 8.1 Hz); δ_C (75 MHz; $CDCl_3$) 38.2, 126.8, 128.2, 128.7, 128.9, 130.4, 133.6, 141.1, 142.2, and 158.0.

N-Benzoyl-2-diazo-N-methylmalonamic Acid Methyl Ester 9

To a solution containing *N*-methylbenzamide (3.0 g, 22.2 mmol) in benzene (40 mL) was added methyl malonyl chloride (3.6 mL, 33.3 mmol). The reaction was heated at reflux for 8 h, after which the

benzene was removed under reduced pressure. The residue was dissolved in CH_2Cl_2, washed once with a saturated $NaHCO_3$ solution, and once with brine. The organic phase was dried over Na_2SO_4, concentrated under reduced pressure and subjected to flash column chromatography to give *N*-methyl-*N*-benzoylmalonamic acid methyl ester **14a** (4.84 g, 93%) as a light yellow oil; ν_{max} (neat)/cm^{-1} 1738, 1680, and 1318; δ_H (300 MHz; $CDCl_3$) 3.20 (3H, s), 3.71 (3H, s), 3.88 (2H, s), and 7.48-7.64 (5H, m); δ_C (75 MHz; $CDCl_3$) 34.9, 44.4, 52.1, 128.2, 128.6, 132.2, 134.1, 167.6, 168.6, and 173.8.

To a solution containing **14a** (4.8 g, 20.4 mmol) in CH_2Cl_2 (150 mL) at 0°C was added triethylamine (11.4 mL, 81.6 mmol). After stirring for 20 min at 0°C, mesyl azide (5.1 mL, 40.8 mmol) was added. The reaction was allowed to warm to room temperature and was stirred for a further 12 h. The reaction was quenched by the addition of a 10% KOH solution, washed once with brine, dried over Na_2SO_4, and concentrated under reduced pressure. The residue was subjected to flash silica gel chromatography to give the diazo compound **9** (4.52 g, 85%) as a yellow oil; ν_{max} (neat)/cm^{-1} 2129, 1716, 1637, and 1296; δ_H (300 MHz; $CDCl_3$) 3.19 (3H, s), 3.51 (3H, s), 7.28 (2H, dd, *J* 9.0 and 6.0 Hz), 7.35 (1H, t, *J* 6.0 Hz), and 7.46 (2H, d, *J* 9.0 Hz); δ_C (75 MHz; $CDCl_3$) 33.9, 52.3, 128.2, 128.7, 132.0, 134.9, 160.7, 166.1, and 172.7.

N-(2-Benzenesulfonyl-2-diazoacetyl)-N-methylbenzamide 10

To a solution containing phenylsulfonyl acetic acid[32] (3.56 g, 17.7 mmol) in benzene (20 mL) was added oxalyl chloride (5.0 mL, 57.7 mmol) which contained 2 drops of DMF. The solution was allowed to stir for 2 h at room temperature, after which time the excess oxalyl chloride was removed under reduced pressure. The crude acid chloride was taken up in benzene (20 mL) and was cannulated into a solution containing *N*-methylbenzamide (2.0 g, 14.8 mmol) in benzene (20 mL), and the mixture was heated at reflux for 8 h. The solution was cooled, concentrated under reduced pressure, taken up in CH_2Cl_2, washed once with a saturated $NaHCO_3$ solution, and then with brine. The combined organic extracts was dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was subjected to flash silica gel chromatography to give *N*-(2-benzenesulfonylacetyl)-*N*-methylbenzamide **14b** (3.39 g, 76%) as a clear oil; ν_{max} (neat)/cm^{-1} 1730, 1675, and 1150; δ_H (300 MHz; $CDCl_3$) 3.15 (3H, s), 4.79 (2H, s), 7.45-7.68 (8H, m), and 7.94 (2H, d, *J* 7.8 Hz); δ_C (75 MHz; $CDCl_3$) 35.2, 61.6, 128.2, 128.6, 129.1, 132.7, 133.5, 134.0, 139.0, 164.3, and 174.1.

To a solution containing **14b** (0.67 g, 2.23 mmol) in CH_2Cl_2 (10 mL) at 0°C was added triethylamine (0.93 mL, 6.69 mmol). The solution was stirred for 20 min at room temperature and this was followed by the dropwise addition mesyl azide (0.73 mL, 2.68 mmol). The solution was allowed to warm to room temperature over 12 h and was then concentrated under reduced pressure to give the crude diazo compound **10**, which was used directly (see below).

2-Diazo-N-{2-[2-(3,4-dimethoxyphenyl)ethyl]hept-6-enoyl}-N-methylmalonamic Acid Ethyl Ester 11

To a solution containing dimethyl malonate (9.33 mL, 81.6 mmol) in DMF (80 mL) was added powdered potassium carbonate (2.26 g, 16.3 mmol) and 3,4-dimethoxyphenethyl bromide (2.0 g, 8.16 mmol). The solution was heated under reflux for 2 h, and was then quenched with a saturated NH_4Cl solution and extracted with CH_2Cl_2. The combined organic phase was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Dimethyl malonate was removed by distillation at 38°C (1.5 mm) to leave behind dimethyl 2-[2-(3,4-dimethoxyphenyl)ethyl]malonate (1.98 g, 86%) as a colourless solid, m.p. 78-79°C; ν_{max}

(neat)/cm^{-1} 1737, 1509, and 1026; δ_H (300 MHz; $CDCl_3$) 2.18 (2H, q, *J* 7.5 Hz), 2.57 (2H, t, *J* 8.1 Hz), 3.35 (1H, t, *J* 7.5 Hz), 3.71 (6H, s), 3.82 (3H, s), 3.84 (3H, s), and 6.67-6.77 (3H, m); δ_C (75 MHz; $CDCl_3$) 30.6, 32.9, 50.8, 52.5, 55.8, 111.2, 111.7, 120.4, 133.0, 147.4, 148.9, and 169.7.

To a solution containing the above malonate (3.91 g, 13.2 mmol) and cesium carbonate (8.60 g, 26.4 mmol) in DMF (200 mL) was added 5-bromopentene (1.88 mL, 15.8 mmol). The solution was heated at 90°C for 12 h, quenched with water, extracted with CH_2Cl_2 and the combined organic phase was washed with brine, dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was subjected to flash silica gel chromatography to give dimethyl 2-[2-(3,4-dimethoxyphenyl)ethyl]-2-pent-4-enylmalonate (4.14 g, 86%) as a pale yellow oil; ν_{max} (neat)/cm^{-1} 1731, 1512, and 1262; δ_H (300 MHz; $CDCl_3$) 1.24-1.35 (2H, m), 1.93-1.99 (2H, m), 2.06 (2H, q, *J* 7.2 Hz), 2.14-2.20 (2H, m), 2.42-2.47 (2H, m), 3.72 (6H, s), 3.84 (3H, s), 3.86 (3H, s), 4.95-5.04 (2H, m), 5.70-5.96 (1H, m), and 6.68-6.79 (3H, m); δ_C (75 MHz; $CDCl_3$) 23.5, 30.2, 32.4, 33.7, 34.6, 52.3, 55.9, 57.5, 65.9, 111.3, 111.7, 115.7, 120.1, 120.8, 133.9, 137.9, 147.4, 148.9, and 172.0.

To a solution containing the above malonate (4.14 g, 11.4 mmol) in water (20 mL) was added KOH pellets (6.37 g, 113.6 mmol). The solution was stirred for 12 h at 90°C and then the aqueous mixture was acidified by the dropwise addition of concentrated HCl. The mixture was extracted with ether, dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was dissolved in xylene (200 mL) and heated at reflux for 24 h. The solvent was removed under reduced pressure to give 2-[2-(3,4-dimethoxyphenyl)ethyl]hept-6-enoic acid (2.62 g, 77%) as a yellow oil; ν_{max} (neat)/cm^{-1} 1733, 1697, and 1020; δ_H (300 MHz; $CDCl_3$) 1.34-1.82 (6H, m), 1.95-2.07 (3H, m), 2.38-2.42 (1H, m), 2.50-2.69 (2H, m), 3.85 (3H, s), 3.87 (3H, s), 4.93-5.02 (2H, m), 5.69-5.84 (1H, m), and 6.71-6.81 (3H, m); δ_C (75 MHz; $CDCl_3$) 26.5, 31.6, 33.2, 33.5, 33.9, 44.7, 55.8, 55.9, 111.3, 111.8, 114.8, 120.2, 134.1, 138.2, 147.3, 148.3, and 182.4.

To a solution containing the above acid (1.0 g, 3.35 mmol) in CH_2Cl_2 (25 mL) was added 1,1'-carbonyl diimidazole (0.65 g, 4.02 mmol). After being stirred for 2 h, the solution was poured into 40% aqueous methylamine at 0°C. The solution was allowed to warm to room temperature overnight, and was then acidified with 6 N HCl and extracted with CH_2Cl_2. The combined organic extracts were washed with brine, dried over $MgSO_4$, filtered and concentrated under reduced pressure to give 2-[2-(3,4-dimethoxyphenyl)ethyl]-*N*-methylhept-6-enamide **15a** (0.96 g, 92%) as a cream coloured solid, m.p. 98-99°C; ν_{max} (neat)/cm^{-1} 2855, 1645, and 1510; δ_H (300 MHz; $CDCl_3$) 1.27-1.49 (3H, m), 1.60-1.74 (2H, m), 1.91-2.06 (3H, m), 2.42-2.65 (3H, m), 2.83 (3H, d, *J* 4.8 Hz), 3.85 (3H, s), 3.86 (3H, s), 4.92-5.00 (2H, m), 5.37 (1H, brs), 5.69-5.83 (1H, m), and 6.67-6.79 (3H, m).

To a solution containing **15a** (1.1 g, 3.53 mmol) in benzene (50 mL) was added ethyl malonyl chloride (0.9 mL, 7.06 mmol). The solution was heated at reflux for 3 h, quenched with a saturated solution of $NaHCO_3$, and extracted with CH_2Cl_2. The combined organic phase was dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was subjected to silica gel flash chromatography to give *N*-{2-[2-(3,4-dimethoxyphenyl)ethyl]hept-6-enoyl}-*N*-methyl malonamic acid ethyl ester (1.43 g, 95%) as a yellow oil; δ_H (300 MHz; $CDCl_3$) 1.27 (3H, t, *J* 7.2 Hz), 1.35-1.79 (9H, m), 1.99-2.06 (2H, m), 2.42-2.65 (2H, m), 2.81-2.84 (1H, m), 3.13 (2H, s), 3.85 (3H, s), 3.86, (3H, s), 4.18 (2H, q, *J* 7.2 Hz), 4.94-5.82 (2H, m), 5.71-5.82 (1H, m), and 6.66-6.80 (3H, m); δ_C (75 MHz; $CDCl_3$) 14.1, 26.4, 31.4, 31.8, 32.8, 33.6, 33.7, 43.7, 46.7, 55.8, 55.9, 61.2, 111.2, 111.6, 115.1, 120.1, 133.7, 138.0, 147.4, 148.9, 169.1, and 179.0.

To a solution containing the above compound (1.36 g, 3.2 mmol) in CH_2Cl_2 (35 mL) at 0°C was slowly added triethylamine (1.78 mL, 12.8 mmol). The solution was stirred for 20 min, and this was followed by the dropwise addition of mesyl azide (0.8 mL, 6.39 mmol). The solution was extracted with CH_2Cl_2 and the combined organic phase was washed with brine, dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was subjected to flash silica gel chromatography to afford the diazo compound **11** (1.31 g, 90%) as a yellow oil; ν_{max} (neat)/cm^{-1} 2134, 1718, 1647, and 1327; δ_H (300 MHz; $CDCl_3$) 1.30 (3H, t, *J* 7.2 Hz), 1.35-1.55 (2H, m), 1.58 (2H, s), 1.68-1.80 (2H, m), 1.98-2.06 (2H, m), 2.52-2.53 (2H, m), 2.93-2.94 (1H, m), 3.13 (3H, s), 3.85 (3H, s), 3.86 (3H, s), 4.27 (2H, q, *J* 7.2 Hz), 4.96-5.01 (2H, m), 5.70-5.84 (1H, m), and 6.68-6.78 (3H, m).

2-Diazo-N-[2-(3,4-Dimethoxyphenyl)ethyl]-N-hept-6-enoylmalonamic Acid Ethyl Ester 12

To a solution containing 6-heptenoic acid[33] (1.09 g, 7.80 mmol) in CH_2Cl_2 (50 mL) was added 1,1'-carbonyldiimidazole (1.73 g, 9.36 mmol), and the solution was stirred at room temperature for 2 h. The reaction mixture was then added to solution of 3,4-dimethoxyphenethylamine (2.02 g, 8.97 mmol) in CH_2Cl_2 (100 mL) at 0°C. The solution was allowed to warm to room temperature, stirred for 10 h, and concentrated under reduced pressure. The residue was subjected to silica gel flash chromatography to give hept-6-enoic acid [2-(3,4-dimethoxyphenyl)ethyl]amide **15b** (2.01 g, 89%) as a colourless solid, m.p. 59-60°C; ν_{max} (neat)/cm^{-1} 1639, 1514, 1233, and 1026; δ_H (300 MHz; $CDCl_3$) 1.35 (2H, quin, *J* 7.2 Hz), 1.58 (2H, quin, *J* 7.2 Hz), 2.01 (2H, q, *J* 7.2 Hz), 2.09 (2H, t, *J* 7.5 Hz), 2.72 (2H, t, *J* 6.9 Hz), 3.46 (2H, q, *J* 6.9 Hz), 3.83 (s, 6H), 4.89-4.98 (2H, m), 5.46 (1H, brs), 5.74 (1H, ddt, *J* 16.8, 10.2 and 6.6 Hz), 6.68 (2H, m), and 6.77 (1H, d, *J* 8.4 Hz); δ_C (75 MHz; $CDCl_3$) 25.2, 28.4, 33.4, 35.3, 36.6, 40.6, 55.9, 111.3, 111.9, 114.6, 120.6, 131.4, 138.3, 147.6, 149.0, and 172.9.

N-Malonylacylation was carried out on the above amide **15b** in the normal manner to give *N*-[2-(3,4-dimethoxyphenyl)ethyl]-*N*-hept-6-enoyl malonamic acid ethyl ester (85%) as a clear oil; ν_{max} (neat)/cm^{-1} 1738, 1696, 1515, and 1028; δ_H (300 MHz; $CDCl_3$) 1.25 (3H, t, *J* 7.2 Hz), 1.27 (2H, m), 1.51 (2H, quin, *J* 7.5 Hz), 1.98 (2H, m), 2.28 (2H, t, *J* 7.5 Hz), 2.81 (2H, t, *J* 7.5 Hz), 3.77 (2H, s), 3.84 (8H, m), 4.16 (2H, q, *J* 7.2 Hz), 4.93 (2H, m), 5.73 (1H, ddt, *J* 17.1, 10.2 and 6.9 Hz), 6.71 (1H, d, *J* 8.7 Hz), 6.72 (1H, s), and 6.77 (1H, d, *J* 8.7 Hz); δ_C (75 MHz; $CDCl_3$) 14.0, 23.8, 28.1, 33.3, 34.6, 36.2, 46.3, 46.4, 55.9, 61.1, 111.4, 112.3, 114.7, 120.7, 130.8, 138.2, 147.9, 149.1, 167.4, 168.7, and 175.8.

The above compound was subjected to the standard diazo transfer conditions to give 2-diazo-*N*-[2-(3,4-dimethoxyphenyl)ethyl]-*N*-hept-6-enoyl malonamic acid ethyl ester **12** as a yellow oil (100%); ν_{max} (neat)/cm^{-1} 2136, 1718, 1647, 1512, and 1024; δ_H (300 MHz; $CDCl_3$) 1.22 (3H, t, *J* 7.2 Hz), 1.32 (2H, quin, *J* 7.2 Hz), 1.56 (2H, quin, *J* 7.2 Hz), 1.98 (2H, q, *J* 7.2 Hz), 2.38 (2H, t, *J* 7.2 Hz), 2.80 (2H, t, *J* 7.2), 3.78 (8H, m), 4.17 (2H, q, *J* 7.2 Hz), 4.89 (2H, m), 5.72 (1H, ddt, *J* 16.8, 10.2 and 6.6 Hz), 6.65 (1H, s), 6.67 (1H, d, *J* 8.7 Hz), and 6.73 (1H, d, *J* 8.7 Hz); δ_C (75 MHz; $CDCl_3$) 14.2, 24.4, 28.2, 33.3, 35.3, 35.8, 48.2, 55.8, 61.7, 72.4, 111.3, 112.3, 114.5, 120.9, 130.8, 138.3, 147.7, 148.9, 160.3, 166.3, and 175.2.

RHODIUM(II) CATALYSED DECOMPOSITION OF DIAZOCARBONYL COMPOUNDS

Rhodium catalysed decomposition of 1

A solution of the diazoamide **1** (0.092 g, 0.297 mmol) in dry CH_2Cl_2 (2 mL) was added to a suspension of rhodium(II) perfluorobutyramide (0.006 g, 2 mol%) in dry CH_2Cl_2 (4 mL) and the mixture stirred at room temperature for 2 h. Then triethylamine (0.05 mL, 0.356 mmol) and TIPSOTf (0.100 g, 0.327 mmol) were added and the mixture stirred for a further 30 min. The reaction mixture was then washed with water (2x10 mL), dried over $MgSO_4$, preadsorbed onto silica and subjected to flash silica gel column chromatography to give *ethyl 1-phenyl-2-triisopropylsiloxyindole-3-carboxylate* **16** (0.069 g, 53%) as a colourless solid, m.p. 92-94°C; (Found: M^+, 437.2340. $C_{26}H_{35}NO_3Si$ requires 437.2386); $\nu_{max}(CH_2Cl_2)/cm^{-1}$ 2946, 2868, 1699, 1549, and 1421; δ_H (250 MHz; $CDCl_3$) 0.93 (18H, d, *J* 6.8 Hz), 1.10 (3H, heptet, *J* 6.8 Hz), 1.44 (3H, t, *J* 7.0 Hz), 4.40 (2H, q, *J* 7.0 Hz), 7.00-6.96 (1H, m), 7.09 (1H, m) 7.20 (1H, m), 7.55-7.37 (5H, m), and 8.07 (1H, dd, *J* 1.05 and 8.3 Hz); δ_C (100.6 MHz; $CDCl_3$) 14.30, 15.17, 18.14, 59.50, 90.76, 109.88, 121.22, 122.40, 125.63, 128.85, 129.78, 132.69, 135.60, 153.44, and 165.22; *m/z* 437 (M^+, 1%), 394 (100), 366 (24), 119 (45), and 59 (40).

Rhodium catalysed decomposition of 2

A solution of the *bis*-diazoamide **2** (0.20 g, 0.406 mmol) in dry CH_2Cl_2 (4 mL) was added to a suspension of rhodium(II) perfluorobutyramide (0.009 g, 2 mol%) in dry CH_2Cl_2 (5 mL) and the mixture stirred at room temperature for 30 min. Then triethylamine (0.136 mL, 0.97 mmol) and TIPSOTf (0.274 g, 0.89 mmol) were added and the mixture stirred for a further 15 min. The reaction mixture was then washed with water (2 x 15 mL), dried over Na_2SO_4, preadsorbed onto silica and subjected to flash silica gel chromatography to give the *bis-indole* **17** (0.276 g, 91%) after one recrystallisation from light petroleum/diethyl ether; m.p. 142-144°C; (Found: M^+, 748.4300. $C_{42}H_{64}N_2O_6Si_2$ requires 748.4300); $\nu_{max}(CH_2Cl_2)/cm^{-1}$ 2949, 2869, 1693, 1545, and 1470; δ_H (250 MHz; $CDCl_3$) 1.08 (36H, d, *J* 7.5 Hz), 1.40 (6H, t, *J* 7.2 Hz), 1.43 (6H, h, *J* 7.5 Hz), 4.32 (4H, q, *J* 7.2 Hz); 4.36 (4H, s), 6.66 (2H, d, *J* 8.0 Hz), 7.08 (2H, dt, *J* 1.6 and 7.6 Hz), and 7.91 (2H, d, *J* 7.6 Hz); δ_C (100.6 MHz; $CDCl_3$) 14.24, 14.76, 17.92, 40.85, 58.98, 90.41, 108.00, 121.00, 121.20, 121.72, 125.31, 130.46, 152.75, and 164.59; *m/z* 748 (M^+), 705 (100%), 186 (12), 87 (21), 73 (30), and 59 (56).

Rhodium catalysed decomposition of 3

(a) A solution of the diazoamide **3** (0.50 g, 1.415 mmol) in benzene (18 mL) was added to a suspension of rhodium(II) acetate (0.013 g, 2 mol%) in benzene (13 mL). The mixture was heated under reflux for 1 h then concentrated under reduced pressure, redissolved in CH_2Cl_2 (30 mL), treated with triethylamine (0.25 mL, 1.79 mmol) and TIPSOTf (0.40 mL, 1.49 mmol) and stirred for 1.5 h. This mixture was then washed with water (2 x 30 mL), dried over $MgSO_4$ and preadsorbed onto silica. The multicomponent mixture was subjected to flash silica gel chromatography to give (i) trans *ethyl 1-(4-methoxyphenyl)-2-oxo-4-phenyl-3-carboxylate* **18** (0.096 g, 21%) as a light yellow oil; (Found: M^+, 325.1310. $C_{19}H_{19}NO_4$ requires 325.1314); ν_{max}(neat)/cm^{-1} 1927, 1761, 1732, 1514, and 1248; δ_H (250 MHz; $CDCl_3$) 1.32 (3H, t, *J* 7.1 Hz), 3.74 (3H, s), 3.95 (1H, d, *J* 2.6 Hz), 4.29 (2H, q, *J* 7.1 Hz), 5.28 (1H, d, *J* 2.6 Hz), 6.81-6.75 (2H, m), 7.25-7.20 (2H, m), and 7.40-7.28 (5H, m); δ_C(62.9 MHz; $CDCl_3$) 14.10, 56.35, 57,52, 61.98, 63,45, 114.26, 118.48, 126.15,

128.92, 129.20, 130.63, 136.33, 156.30, 158.65, and 166.38; *m/z* 325 (M^+, 43%), 149 (100), 103 (52), and 77 (42); and (ii) *ethyl 1-benzyl-5-methoxy-2-triisopropylsiloxyindole-3-carboxylate* **19** (0.085 g, 13%) as a pale yellow oily solid which characterised as detailed below

(b) A solution of the diazoamide **3** (0.200 g, 0.566 mmol) in CH_2Cl_2 (5 mL) was added to a suspension of rhodium(II) perfluorobutyramide (0.012 g, 2 mol %) in CH_2Cl_2 (7 mL) and the mixture stirred for 45 min at room temperature. Treatment with triethylamine (0.10 mL, 0.718 mmol) and TIPSOTf (0.17 mL, 0.632 mmol), aqueous workup and flash silica gel chromatography in the standard manner gave *ethyl 1-benzyl-5-methoxy-2-triisopropylsiloxyindole-3-carboxylate* **19** (0.248 g, 91%) as a colourless oil which crystallised to give a low melting solid, m.p. 52-62°C; (Found: M^+, 481.2655. $C_{28}H_{39}NO_4Si$ requires 481.2648); ν_{max} (neat)/cm^{-1} 2945, 2867, 1695, 1535; δ_H (250 MHz; $CDCl_3$) 1.08 (18H, d, *J* 7.5 Hz), 1.44 (3H, t, *J* 7.1 Hz), 1.47 (3H, heptet, *J* 7.5 Hz), 3.84 (3H, s), 4.37 (2H, q, *J* 7.1 Hz), 5.25 (2H, s), 6.68 (1H, dd, *J* 2.6 and 8.7 Hz), 6.89 (1H, d, *J* 8.7 Hz), 7.10-7.02 (2H, m), 7.30-7.20 (3H, m), and 7.595 (1H, d, *J* 2.6 Hz); δ_C (100.6 MHz; $CDCl_3$) 14.34, 17.78, 17.94, 44.89, 55.72, 59.04, 65.85, 89.44, 104.42, 109.85, 110.02, 125.74, 126.16, 126.21, 127.44, 128,72, 136.41, 153.33, 155.69, and 164.83; *m/z* 481 (M^+), 438 (28%), 91 (28), 28 (100).

(c) Similarly, treatment of diazoamide **3** (0.250 g, 0.707 mmol) with rhodium(II) trifluoroacetamide (0.096 g, 2 mol %) gave the same indole **19** (0.317 g, 93%) after derivatisation of the intermediate oxindole, work up, and purification.

Rhodium catalysed decomposition of 4

(a) To a solution of diazoamide **4** (0.432 g, 1.22 mmol) in dry CH_2Cl_2 (80 mL) was added rhodium(II) acetate (0.022 g, 4 mol%) and the mixture stirred at room temperature for 23 h then preadsorbed onto silica and subjected to flash silica gel chromatography to give trans *ethyl 1-(3-methoxyphenyl)-2-oxo-4-phenyl-3-carboxylate* **20** (0.121 g, 27%) as colourless crystals, m.p. 130-132°C (light petroleum/diethyl ether); (Found: M^+, 325.1321. $C_{19}H_{19}NO_4$ requires 325.1314); ν_{max} (CH_2Cl_2)/cm^{-1} 1767, 1732, 1603, and1496; δ_H (400 MHz; $CDCl_3$) 1.32 (3H, t, *J* 7.2 Hz), 3.72 (3H, s), 3.96 (1H, d, *J* 2.65 Hz), 4.28 (2H, q, *J* 7.2 Hz), 5.30 (1H, d, *J* 2.65 Hz), 7.20-6.55 (4H, m), and 7.50-7.30 (5H, m); δ_C (100.6 MHz; $CDCl_3$) 14.18, 55.27, 57.74, 62.11, 63.54, 103.18, 109.38, 110.37, 126.18, 129.04, 129.32, 129.92, 136.34, 138.28, 159.34, 160.14, and 166.25; *m/z* 326 (MH^+, 12%), 149 (100), 131 (26), and 77 (19).

(b) A solution of diazoamide **4** (0.200 g, 0.566 mmol) in dry CH_2Cl_2 (6 mL) was added to a suspension of rhodium(II) perfluorobutyramide (0.012 g, 2 mol%) in dry CH_2Cl_2 (7 mL) and the mixture stirred at room temperature 2 h; this was then treated with triethylamine (0.10 mL, 0.68 mmol) and TIPSOTf (0.191 g, 0.623 mmol), washed with water (2 x 20 mL), preadsorbed onto silica and subjected to flash silica gel chromatography to give (i) *ethyl 1-benzyl-6-methoxy-2-triisopropylsiloxyindole-3-carboxylate* **21** (0.166 g, 63%), m.p. 93-95°C; (Found: M^+, 481.2625. $C_{28}H_{39}NO_4Si$ requires 481.2648); ν_{max} (CH_2Cl_2)/cm^{-1} 2945, 2867, 1696, 1547, and 1112; δ_H (250 MHz; $CDCl_3$) 1.07 (18H, d, *J* 7.5 Hz), 1.43 (3H, t, *J* 7.1 Hz), 1.46 (3H, heptet, *J* 7.5 Hz), 3.74 (3H, s), 4.36 (2H, q, *J* 7.1 Hz), 5.22 (2H, s), 6.535 (1H, d, *J* 2.3 Hz), 7.30-6.75 (6H, m), and 7.89 (1H, d, *J* 8.7 Hz); δ_C (100.6 MHz; $CDCl_3$) 14.3, 14.8, 17.9, 44.8, 55.7, 59.1, 88.8, 94.7, 109.5, 119.1, 121.6, 126.2, 127.4, 128.7, 131.7, 136.3, 152.7, 155.6, and 164.8; *m/z* 482 (MH^+), 481 (M^+), 438 (70), 155 (7), 91 (12), 51(14), 28 (100); and (ii) *ethyl 1-benzyl-4-methoxy-2-triisopropylsiloxyindole-3-carboxylate* **22** (0.062g, 21%), m.p. 95-96°C (pentane); (Found: M^+, 481.2653. $C_{28}H_{39}NO_4Si$ requires 481.2648); ν_{max} (CH_2Cl_2)/cm^{-1} 2945, 2867, 1690, and 1547, 1452, δ_H (250 MHz; $CDCl_3$) 1.06 (18H, d, *J* 7.5 Hz), 1.40 (3H, t,

J 7.1 Hz) 1.44 (3H, h, *J* 7.5 Hz), 3.90 (3H, s), 4.35 (2H, q, *J* 7.1 Hz), 5.24 (2H, s), 6.68-6.60 (2H, m), and 7.30-6.95 (6H, m); δ_C (100.6 MHz; $CDCl_3$) 14.1, 14.6, 17.9, 45.0, 155.5, 59.8, 89.8, 102.8, 103.3, 113.9, 121.9, 126.2, 127.3, 128.6, 132.4, 136.5, 150.4, 152,9 and 165.6; *m/z* 482 (MH^+), 481 (M^+), 438 (20%), 155 (23), 113 (25), 51(64), 32(100).

Rhodium catalysed decomposition of 5

(a) A solution of diazoamide **5** (1.0 g, 2.83 mmol) in dry CH_2Cl_2 (20 mL) was added to a stirred suspension of rhodium(II) acetate (0.114 g, 9 mol%) in dry CH_2Cl_2 (30 mL) and the mixture stirred at room temperature for 40 h, then refluxed for a further 1 h until all the diazoamide had been consumed. The resulting multicomponent mixture was preadsorbed on silica and subjected to flash silica gel chromatography to give (i) trans *ethyl 4-(4-methoxyphenyl)-2-oxo-1-phenyl-3-carboxylate* **23** (0.252 g, 27%) as a yellow oil; (Found: M^+, 325.1334. $C_{19}H_{19}NO_4$ requires 325.1314); ν_{max}/cm^{-1} (neat) 2982, 2935, 2838, 1764, 1730, 1515, and 1250; δ_H (250 MHz; $CDCl_3$) 1.32 (3H, t, *J* 7.1 Hz), 3.80 (3H, s), 3.95 (1H, d, *J* 2.6 Hz), 4.28 (2H, q, *J* 7.1 Hz), 5.27 (2H, d, *J* 2.6 Hz), 6.94-6.87 (2H, m). 7.10-7.01 (1H, m), 7.35-7.20 (6H, m); δ_C (100.6 MHz; $CDCl_3$) 14.18, 55.35, 57.37, 62.06, 63.70, 114.69, 117.23, 124.33, 127.54, 128.13, 129.07, 137.23, 159.41, 160.13, 166.41; *m/z* 326 (MH^+), 325 (M^+), 206 (100%), 178(9), 161 (60), 134 (37), 91 (17) and 77(33); and (ii) *ethyl 6-methoxy-3-oxo-2-phenyl-1,2,3,3a-tetrahydrocyclohepta[c]pyrrole-3a-carboxylate* **24** (0.043g, 5%) as colourless crystals after trituration (light petroleum/diethyl ether) and recrystallisation (diethyl ether) of certain mixed fractions from the column, m.p. 110-112°C, (Found: M^+, 325.1314. $C_{19}H_{19}NO_4$ requires 325.1314); ν_{max} (CH_2Cl_2)/cm^{-1} 1745, 1706, 1403, 1235, and 1222; δ_H (250 MHz; $CDCl_3$) 1.16 (3H, t, *J* 7.1 Hz), 3.63 (3H, s), 4.25-4.00 (2H, m), 4.56 (1H, dd, *J* 14.1, and 1.6 Hz), 4.84 (1H, dq, *J* 14.1 and 0.7 Hz), 5.70 (1H, dd, *J* 7.3, and 1.6 Hz), 5.84 (1H, d, *J* 10.5 Hz), 6.30 (1H, td, *J* 7.3, and 2.1 Hz), 6.35 (1H, dd, *J* 10.5, and 2.1 Hz), and 7.75-7.15 (5H, m); δ_C (100.6 MHz; $CDCl_3$) 14.0, 52.0, 54.9, 60.7, 52.0, 101.6, 119.1, 120.3, 123.4, 124.4, 125.4, 126.4, 129.1, 138.6, 159.2, 168.0, and 170.1; *m/z* 326 (MH^+), 325 (M^+), 252 (100%), and 77 (19).

(b) A solution of diazoamide **5** (0.230 g, 0.651 mmol) in dry CH_2Cl_2 (5 mL) was added to a stirred suspension of rhodium(II) perfluorobutyramide (0.014 g, 2 mol%) in dry CH_2Cl_2 (8 mL) and stirring was maintained for 70 min. The reaction mixture was then treated with triethylamine (0.11 mL, 0.78 mmol) and TIPSOTf (0.20 mL, 0.70 mmol); after 30 min it was washed with water (2 x 20 mL), dried over $MgSO_4$ and preadsorbed on silica before subjecting to flash silica gel chromatography to yield, after recrystallisation, *ethyl 1-(4-methoxybenzyl)-2-triisopropylsiloxyindole-3-carboxylate* **25** (0.286 g, 91%) as colourless plates, m.p. 122-124°C (light petroleum/diethyl ether); (Found: M^+, 481.2655. $C_{28}H_{39}NO_4Si$ requires 481.2653); ν_{max}(CH_2Cl_2)/cm^{-1} 2956, 2870, 1693, 1541, and 1142; δ_H (250 MHz; $CDCl_3$) 1.09 (18H, d, *J* 7.5 Hz), 1.43 (3H, t, *J* 7.1Hz), 1.50 (3H, h, 7.5 Hz), 3.74 (3H, s), 4.37 (2H, q, *J* 7.1 Hz), 5.21 (2H, s), 6.81-6.76 (2H, m), 7.20-6.95 (5H, m), and 8.01 (1H, d, *J* 7.5 Hz)); δ_C (100.6 MHz; $CDCl_3$)14.35, 14.76, 17.96, 44.22, 55.22, 59.09, 89.17, 109.36, 114.07, 120.82, 121.13, 121.16, 125.30, 127.50, 128.37, 130.90, 153.20, 158.87, and 164.90; *m/z* 482 (MH^+), 481 (M^+), 438 (25%), 121 (100), 73 (7), and 28 (27).

Rhodium catalysed decomposition of 6

(a) A solution of the diazoamide **6** (0.125 g, 0.371 mmol) in dry CH_2Cl_2 (4 mL) was added to a suspension of rhodium(II) acetate (0.003 g, 2 mol%) in dry CH_2Cl_2 (4 mL) and the mixture stirred at room

temperature for 22 h. A further 4 mol% (0.007g) of rhodium(II) acetate was then added and the mixture refluxed for 2 h until all the starting diazoamide was consumed. NMR analysis of the crude mixture showed 3 significant components which were separated by subjecting the mixture to flash silica gel chromatography. Thus were isolated (i) trans *ethyl 1-benzyl-2-oxo-4-phenyl-3-carboxylate* **26** (0.034 g, 39%) as a colourless oil; ν_{max} (neat)/cm^{-1} 2984, 1770, 1732, and 1194; (Found: M$^+$, 309.1343. $C_{19}H_{19}NO_3$ requires 309.1365); δ_H (250 MHz; $CDCl_3$) 1.30 (3H, t, *J* 7.1 Hz), 3.83 (1H, d, *J* 15.2 Hz), 3.91 (1H, d, *J* 2.2 Hz), 4.25 (2H, q, *J* 7.1 Hz), 4.70 (1H, d, *J* 2.2 Hz), 4.25 (2H, q, *J* 7.1 Hz), 4.70 (1H, d, *J* 2.2 Hz), 4.87 (1H, d, *J* 15.2 Hz), and 7.40-7.15 (10H, m); δ_C (100.6 MHz; $CDCl_3$) 14.13, 44.88, 57.13, 61.79, 63.54, 126.80, 127.84, 128.28, 128.79, 129.03, 129.13, 134.75, 136.08, 162.40, and 166.79; *m/z* 309 (M$^+$, 2%), 176 (68), 103 (45), 91 (100), and 77 (39); (ii) cis *ethyl 1-benzyl-2-oxo-4-phenyl-3-carboxylate* **27** (28% from ^{1}H NMR) as a colourless oil which was characterised as detailed below, and (iii) *ethyl 2-benzyl-3-oxo-1,2,3,3a-tetrahydrocyclohepta[c]pyrrole-3a-carboxylate* **28** (0.023 g, 22%) as a crystalline solid which was characterised as detailed below.

(b) A solution of the diazoamide **6** (0.100 g, 0.296 mmol) in dry CH_2Cl_2 (2.1 mL) was added to a suspension of rhodium(II) perfluorobutyramide (0.006 g, 2 mol%) in dry CH_2Cl_2 (4.2 mL) and the mixture stirred at room temperature for 18 h, then preadsorbed onto silica and subjected to flash silica gel chromatography (1:1 light petroleum:diethyl ether) to give (i) *ethyl 2-benzyl-3-oxo-1,2,3,3a-tetrahydrocyclohepta[c]pyrrole-3a-carboxylate* **28** (0.064 g, 70%) as colourless crystals, m.p. 92-94°C; (Found: C, 73.58; H, 6.04; N, 4.76. $C_{19}H_{19}NO_3$ requires C, 73.77; H, 6.19; N, 4.53%); $\nu_{max}(CH_2Cl_2)$/cm^{-1} 1746, 1699, and 1205; δ_H (250 MHz; $CDCl_3$) 1.15 (3H, t, *J* 7.1 Hz), 4.00 (1H, dd, J, 14.95, and 1.5 Hz), 4.07 (2H, m), 4.27 (1H, dd, *J* 14.95, and 2.2 Hz), 4.44 (1H, d, *J* 14.85 Hz), 4.79 (1H, d, *J* 14.85 Hz), 5.08-5.60 (1H, m), 6.25-6.20 (1H, m), 6.50-6.40 (3H, m), and 7.36-7.22 (5H, m); δ_C (100.6 MHz; $CDCl_3$) 14.03, 46.83, 50.26, 59.99, 61.77, 120.58, 122.51, 127.85, 128.01, 128.12, 128.40, 128.813, 129.93, 130.56, 135.61, 167.77, and 171.10; *m/z* 309 (M$^+$), 236, and 91 (100); and (ii) cis *ethyl 1-benzyl-2-oxo-4-phenyl-3-carboxylate* **27** (0.011g, 12%) as a colourless oil; (Found: M$^+$, 309.1365. $C_{19}H_{19}NO_3$ requires 309.1365); ν_{max}(neat)/cm^{-1} 1770, 1732, and 1185; δ_H (250 MHz; $CDCl_3$) 0.85 (3H, t, *J* 7.1 Hz), 3.78 (2H, m), 3.94 (1H, d, *J* 14.9 Hz), 4.31 (1H, d, *J* 6.05 Hz), 4.72 (1H, d, *J* 6.05 Hz), 4.94 (1H, d, *J* 14.9 Hz), and 7.39-7.10 (10H, m); δ_C (100.6 MHz; $CDCl_3$) 13.65, 44.97, 56.83, 60.70, 61.11, 127.35, 127.99, 128,59, 128.62, 128.81, and 128.89; *m/z* 309 (M$^+$, 2%), 176 (96), 131 (100), and 91 (75).

Rhodium catalysed decomposition of 7

(a) To a solution containing **7** (0.15 g, 0.8 mmol) in CH_2Cl_2 (4 mL) was added rhodium(II) acetate (2 mg). The solution was stirred at 25°C for 7 h, concentrated under reduced pressure and the residue was subjected to flash silica gel chromatography to give 2-cyano-2-(3-cyano-1-methyl-2-oxo-2,3-dihydro-1*H*-indol-3-yl)-*N*-methyl-*N*-phenylacetamide **29** (0.12 g, 87%) as a 1:1-mixture of diasteromers, m.p. 170-171°C; ν_{max} (neat)/cm^{-1} 2242, 1730, and 1674; δ_H (300 MHz; $CDCl_3$) diasteromer **29a**: 3.17 (3H, s), 3.30 (3H, s), 4.37 (1H, s), 6.92 (1H, d, *J* 7.8Hz), 7.26-7.70 (7H, m) and 7.76 (1H, d, *J* 7.8Hz); diasteromer **29b**: 3.26 (3H, s), 3.33 (3H, s), 4.45 (1H, s), 6.97 (1H, d, *J* 7.8Hz), 7.26-7.70 (7H, m) and 7.93 (1H, d, *J* 7.5Hz). The structure of **29a** was unequivocably established by an X-ray crystal analysis.

(b) To a solution containing of **7** (0.20 g, 1.0 mmol) in CH_2Cl_2 (8 mL) was added a catalytic amount of rhodium(II) perfluorobutyramide. The solution was stirred for 20 min, filtered through a small amount of Celite, and concentrated under reduced pressure to give 1-methyl-2-oxo-2,3-dihydro-1*H*-indole-3-carbonitrile

30 (0.17 g, 98%); ν_{max} (neat)/cm^{-1} 2190, 1720, and 1605; δ_H (300 MHz; $CDCl_3$) 3.24 (1H, s), 4.52 (1H, s), 6.87 (1H, d, *J* 7.8 Hz), 7.15 (1H, t, *J* 7.6 Hz), and 7.38-7.44 (2H, m).

To a solution containing the above oxindole **30** in CH_2Cl_2 (10 mL) was added triisopropylsilyl chloride (0.24 mL, 1.1 mmol) and the solution was cooled to 0°C. Triethylamine (0.15 mL, 1.1 mmol) was added dropwise and the solution was allowed to stir at room temperature for 30 min, before being diluted with CH_2Cl_2 (10 mL), washed with water, dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was subjected to flash silica gel chromatography to give *1-methyl-2-triisopropylsiloxy-1H-indole-3-carbonitrile* **31** (0.19 g, 57%) as a colourless oil; (Found: M$^+$, 229.1972. $C_{19}H_{28}N_2OSi$ requires 229.1974); ν_{max} (neat)/cm^{-1} 2207, 1730, and 1553; δ_H (300 MHz; $CDCl_3$) 1.17 (18H, d, *J* 7.5 Hz), 1.52-1.62 (3H, m), 3.57 (3H, s), 7.17-7.21 (3H, m), and 7.52-7.55 (1H, m); δ_C (75 MHz; $CDCl_3$) 13.4, 17.8, 28.0, 67.7, 109.0, 116.3, 118.2, 121.8, 121.9, 126.0, 131.1, and 153.7.

Rhodium catalysed decomposition of 8

To a solution containing **8** (0.10 g, 0.32 mmol) in CH_2Cl_2 (5 mL) was added a catalytic amount of rhodium(II) perfluorobutyramide. The solution was stirred at room temperature for 8 h, filtered through Celite, and concentrated under reduced pressure to give *3-benzenesulfonyl-1-methyl-1,3-dihydro-indol-2-one* **32** (0.91 g, 100%); (Found: C, 62.56; H, 4.58; N, 4.89. $C_{15}H_{13}NO_3S$ requires C, 62.70; H, 4.56; N, 4.88%); ν_{max} (neat)/cm^{-1} 1714, 1605, and 1146; δ_H (300 MHz; $CDCl_3$) 2.99 (3H, s), 4.90 (1H, s), 6.68 (1H, d, *J* 7.8 Hz), 7.16 (1H, t, *J* 7.8 Hz), 7.37 (1H, t, *J* 7.5 Hz), 7.44 (2H, t, *J* 7.8 Hz), 7.61 (1H, t, *J* 7.5 Hz), and 7.71 (3H, d, *J* 7.5 Hz); δ_C (75 MHz; $CDCl_3$) 26.4, 68.3, 108.4, 118.1, 127.1, 128.5, 129.4, 130.6, 134.3, 135.9, 144.7, and 166.5.

Rhodium catalysed decomposition of 9

To a solution containing **9** (0.50 g (1.91 mmol) in CH_2Cl_2 (25 mL) was added *N*-phenylmaleimide (0.40 g, 2.3 mmol) and rhodium(II) perfluorobutyrate (2 mg). The reaction was stirred at room temperature for 8 h and the solvent was removed under reduced pressure. The residue was taken up in ether and the resultant colourless solid was filtered and washed with ether to give *methyl 8-methyl-3,5,9-trioxo-4,7-diphenyl-10-oxa-4,8-diaza-tricyclo[5.2.1.0^{2,6}]decane-1-carboxylate* **33** (0.67 g, 89%) as a colourless solid, m.p. 148-149°C; (Found: C, 62.97; H, 4.86; N, 7.52. $C_{20}H_{18}N_2O_6$ requires C, 62.82; H, 4.74; N, 7.33%); ν_{max} (neat)/cm^{-1} 1759, 1716, and 1381; δ_H (300 MHz; $CDCl_3$) 2.64 (3H, s), 3.66 (1H, d, *J* 6.7 Hz), 3.95 (1H, d, *J* 6.7 Hz), 4.04 (3H, s), 7.12 (2H, d, *J* 7.5 Hz), 7.33-7.39 (3H, m), 7.50-7.52 (3H, m), and 7.78-7.81 (2H, m); δ_C (75 MHz; $CDCl_3$) 26.1, 49.4, 52.0, 53.4, 86.7, 99.3, 126.2, 127.9, 128.0, 128.4, 128.9, 129.1, 130.9, 131.1, 162.8, 166.6, 170.2, and 171.1.

Rhodium catalysed decomposition of 10

The crude **10** was dissolved in benzene (25 mL) and *N*-phenylmaleimide (0.46 g, 2.67 mmol) was added in one portion. The mixture was heated at 60°C in the presence of rhodium(II) acetate (2 mg) for 8 h and was then concentrated under reduced pressure. The residue was subjected to flash silica gel chromatography to give *1-benzenesulfonyl-8-methyl-4,7-diphenyl-10-oxa-4,8-diazatricyclo[5.2.1.0^{2,6}]decane-3,5,9-trione* **34** (0.52 g, 49%) as a colourless crystalline solid, m.p. 209-210°C; (Found: C, 64.17; H, 4.29; N, 5.79; S, 6.71. $C_{26}H_{20}N_2O_6S$ requires C, 63.92; H, 4.13; N, 5.74; S, 6.55%); ν_{max} (neat)/cm^{-1} 1727, 1377,

and 1173; δ_H (300 MHz; $CDCl_3$) 2.40 (3H, s), 4.41 (2H, d, *J* 8.5Hz), 4.48 (2H, d, *J* 8.5Hz), 7.17-7.21 (2H, m), 7.40-7.81 (6H, m), and 8.22 (2H, d, *J* 7.2 Hz); δ_C (75 MHz; $CDCl_3$) 27.5, 47.4, 55.5, 96.3, 98.6, 126.6, 128.5, 129.1, 129.3, 130.9, 131.4, 135.0, 135.3, 163.3, 167.9, and 169.9.

To a solution containing **34** (0.10 g, 0.23 mmol) in CH_2Cl_2 (5 mL) at 0°C was added boron trifluoride etherate (0.11 mL, 0.92 mmol) and the mixture was heated at reflux for 14 h. The reaction was quenched by the addition of 95% ethanol (1 mL) and the mixture was washed once with water and once with brine. The combined organic phase was dried over Na_2SO_4 and concentrated under reduced pressure to afford an oily residue which consisted mostly of pyridone **35**. The crude oil was dissolved in CH_2Cl_2 (5 mL) and was treated with triisopropylsilyl chloride (0.11 mL, 0.53 mmol) followed by the dropwise addition of triethylamine (0.08 mL, 0.57 mmol). After stirring for 8 h at room temperature, the mixture was then diluted with CH_2Cl_2 (5 mL) washed once with water and once with brine. The combined organic phases were dried over Na_2SO_4 and concentrated under reduced pressure to afford the *pyridone* **36** as a light yellow oil; (FAB/LSIMS; Found: M^+, 509.2448. $C_{29}H_{34}N_2O_4SiLi$ requires 509.2447); ν_{max} (neat)/cm^{-1} 1716, 1645, and 1367; δ_H (300 MHz; $CDCl_3$) 0.97 (6H, s), 1.08 (6H, s), 1.10 (6H, s), 1.38-1.53 (3H, m), 3.28 (3H, s), 7.23-7.32 (6H, m), and 7.43-7.46 (4H, m); δ_C (75 MHz; $CDCl_3$) 12.3, 14.2, 17.7, 18.0, 34.5, 106.2, 117.2, 126.7, 127.5, 128.0, 128.7, 128.8, 129.4, 130.1, 130.6, 131.3, 131.6, 133.6, 136.5, 141.9, 143.0, 161.6, 163.6, and 164.1.

Rhodium catalysed decomposition of 11

To a solution containing diazo compound **11** (1.46 g, 3.23 mmol) in CH_2Cl_2 (50 mL) was added a catalytic amount of rhodium(II) perfluorobutyrate. The solution was allowed to stir for 5 h at room temperature and the solvent was removed under reduced pressure. The residue was subjected to flash silica gel chromatography to give *ethyl 2-[2-(3,4-dimethoxyphenyl)ethyl]-10-methyl-9-oxo-11-oxa-10-aza-tricyclo-[6.2.1^{0,6}]undecane-8-carboxylate* **37** (1.09 g, 80%) as a clear viscous oil; (Found: M^+, 417.2131. $C_{23}H_{31}NO_6$ requires 417.2151); ν_{max} (neat)/cm^{-1} 1657, 1299, and 1140; δ_H (300 MHz; $CDCl_3$) 1.19-1.22 (3H, m), 1.34 (3H, t, *J* 7.2 Hz), 1.68-2.20 (11H, m), 2.47 (3H, s), 2.76-2.80 (1H, m), 3.86 (3H, s), 3.87 (3H, s), 4.28-4.39 (1H, m), and 6.70-6.81 (3H, m); δ_C (75 MHz; $CDCl_3$) 14.2, 24.4, 24.9, 16.6, 31.2, 32.4, 33.3, 35.6, 37.4, 40.7, 55.8, 55.9, 62.0, 85.8, 98.8, 111.3, 111.7, 120.4, 134.3, 147.3, 148.9, 166.0, and 171.4.

Rhodium catalysed decomposition of 12

A solution of of diazoimide **12** (0.99 g, 2.23 mmol) in CH_2Cl_2 (15 mL) at room temperature was treated with rhodium(II) perfluorobutyrate (5 mg). The reaction mixture was stirred for 24 h at room temperature and was then concentrated under reduced pressure. The resulting residue was purified by flash silica gel chromatography to give *ethyl 10-[2-(2,3-dimethoxyphenyl)ethyl]-9-oxo-11-oxa-10-aza-tricyclo-[6.2.1.0^{1,6}]undecane-8-carboxylate* **38** (0.93 g, 100%) as a clear oil; (Found: M^+, 403.1981. $C_{22}H_{29}NO_6$ requires 403.1994); ν_{max} (neat)/cm^{-1} 1749, 1720, 1516, and 1263; δ_H (300 MHz; $CDCl_3$) 1.15 (2H, m), 1.33 (3H, t, *J* 7.2 Hz), 1.57-1.84 (7H, m), 2.15 (2H, m), 2.75 (2H, m), 3.25 (1H, m), 3.42 (1H, m), 3.83 (6H, d, *J* 6.3 Hz), 4.34 (2H, q, *J* 7.2 Hz), 6.71 (2H, m), and 6.77 (1H, d, *J* 8.7 Hz); δ_C (75 MHz; $CDCl_3$) 14.2, 21.4, 24.5, 27.4, 32.5, 35.2, 36.8, 41.5, 42.0, 55.9, 62.0, 85.8, 96.6, 111.3, 112.0, 120.6, 130.7, 147.7, 148.9, 166.0, and 171.1.

To a solution containing the cycloadduct **38** (0.20 g, 0.47 mmol) in CH_2Cl_2 (2 mL) at room temperature was added boron trifluoride etherate (0.11 g, 0.95 mmol). After stirring at 55°C for 5 h, the reaction mixture was cooled to room temperature, quenched with MeOH (2 mL) and diluted with CH_2Cl_2. The organic layer was washed with brine and dried over Na_2SO_4. The organic extract was filtered and concentrated under reduced pressure. The crude residue was subjected to silica gel flash chromatography to give *ethyl 2-hydroxy-6,7-dimethoxy-3-oxo-1,2,3,4,5,10,11,12,13,13a-decahydro-3a-aza-benzo[d]phenanthrene-2-carboxylate* **39** (183 mg, 91%) as a colourless solid, m.p. 159-160°C; (Found: C, 65.38; H, 7.29; N, 3.42. $C_{22}H_{29}NO_6$ requires C, 65.49; H, 7.26; N, 3.47%); ν_{max} (neat)/cm^{-1} 1750, 1643, and 1228; δ_H (300 MHz; $CDCl_3$) 0.79 (3H, t, *J* 7.2 Hz), 1.28-1.47 (4H, m), 1.61-1.76 (3H, m), 1.97 (1H, m), 2.27 (2H, m), 2.52 (2H, m), 3.02 (1H, ddd, *J* 16.5, 12.0 and 7.8 Hz), 3.30 (1H, ddd, *J* 19.5, 12.0 and 5.4 Hz), 3.74 (3H, s), 3.78 (3H, s), 3.85 (2H, m), 3.94 (1H, s), 4.64 (1H, dd, *J* 13.5 and 7.8 Hz), 6.49 (1H, s), and 6.61 (1H, s); δ_C (75 MHz; $CDCl_3$) 13.3, 21.4, 25.9, 27.1, 27.3, 33.9, 35.4, 36.4, 41.0, 55.8, 56.2, 61.7, 61.8, 74.1, 106.3, 112.5, 127.0, 134.5, 147.2, 147.8, 170.9, and 172.9.

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† Author to whom correspondence regarding the X-ray crystallographic determinations of structures **29** and **39** should be directed; correspondence regarding the X-ray crystallographic determinations of the other structures should be addressed to AMZS.

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