

## Synthesis of 3-Aryl-2-methoxyinden-1-one (*Z*)-Phenylhydrazones via Hydrobromic Acid-Mediated Cyclization of 2-(1-Aryl-2-methoxyethenyl)benzaldehyde Phenylhydrazones

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2-(1-Aryl-2-methoxyethenyl)benzaldehydes **2**, obtained by successive treatment of 1-(1-aryl-2-methoxyethenyl)-2-bromobenzenes **1** with BuLi and 1-formylpiperidine, were transformed to the corresponding phenylhydrazones **3** on treatment with PhNHNH<sub>2</sub>. When these hydrazones were allowed to react with conc. HBr, cyclization, followed by dehydrogenation with air occurred, furnished 3-aryl-2-methoxyinden-1-one (*Z*)-phenylhydrazones **4**.

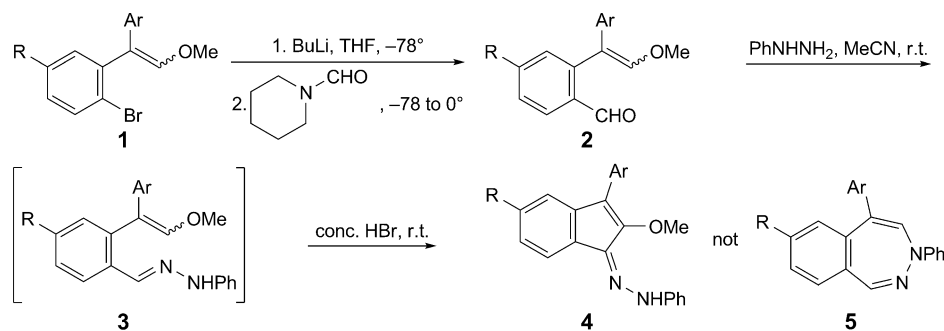
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**Introduction.** – In previous papers, we reported that the reactions of 1-lithio-2-(2-methoxyethenyl)benzenes, generated from 1-bromo-2-(2-methoxyethenyl)benzenes and BuLi, with various electrophiles, followed by conc. HI-mediated cyclization, afforded fused heterocycles [1] and fused aromatics [2]. Herein, we wish to report that the reaction of 1-(1-aryl-2-methoxyethenyl)-2-lithiobenzenes with 1-formylpiperidine afforded 2-(1-aryl-2-methoxyethenyl)benzaldehydes **2**, and that, interestingly, treatment of the corresponding phenylhydrazones **3**, derived from these aldehydes and PhNHNH<sub>2</sub>, with conc. HI or HBr led to the formation of 3-aryl-2-methoxyinden-1-one (*Z*)-phenylhydrazones **4**. Although *Hartke* and *Uhde* reported the formation of 3-acetyl-2-methoxyinden-1-one hydrazones by the treatment of 3-acetyl-2-methoxyindene with diazo compounds [3a], there are no general methods for the preparation of 2-alkoxyinden-1-one hydrazones available [3].

**Results and Discussion.** – Our synthesis of 3-aryl-2-methoxyinden-1-one (*Z*)-phenylhydrazones **4** was conducted as outlined in *Scheme 1*. 1-Bromo-2-(1-aryl-2-methoxyethenyl)benzenes **1** were readily converted to 2-(1-aryl-2-methoxyethenyl)benzaldehydes **2** in fair-to-good yields on successive treatment with BuLi and 1-formylpiperidine. The results are compiled in *Table 1*. Stereoisomers of each product were generally separable by fractional column chromatography (CC) on SiO<sub>2</sub>, while stereoisomers of compound **2c** could not be separated (*Entry 3*), and (*E*)-**2d** was obtained exclusively (*Entry 4*). The reason for this exclusive formation is unclear yet.

We initially investigated the possibility of the formation of 3,5-diphenyl-2,3-benzodiazepine (**5**, R = H, Ar = Ph) by a successive treatment of 2-(2-methoxy-1-phenylethenyl)benzaldehyde (**2a**) with PhNHNH<sub>2</sub> and conc. HI. Thus, compound (*E*)-**2a** was treated with 1 equiv. of PhNHNH<sub>2</sub> in MeCN at room temperature overnight.

Scheme 1

Table 1. Preparation of 2-(1-Aryl-2-methoxyethenyl)benzaldehydes **2**

Entry	<b>1</b>	R	Ar	<b>2</b>	Yield <sup>a)</sup> [%]	( <i>E</i> )/( <i>Z</i> ) <sup>b)</sup>
1	<b>1a</b>	H	Ph	<b>2a</b>	79	5 : 5 <sup>c)</sup>
2	<b>1b</b>	H	4-Me-C <sub>6</sub> H <sub>4</sub>	<b>2b</b>	75	5 : 5 <sup>c)</sup>
3	<b>1c</b>	H	4-( <i>t</i> -Bu)-C <sub>6</sub> H <sub>4</sub>	<b>2c</b>	69	5 : 5 <sup>d)</sup>
4	<b>1d</b>	H	4-Ph-C <sub>6</sub> H <sub>4</sub>	<b>2d</b>	64	10 : 0
5	<b>1e</b>	H	4-Cl-C <sub>6</sub> H <sub>4</sub>	<b>2e</b>	79	6 : 4 <sup>c)</sup>
6	<b>1f</b>	H	3-MeO-C <sub>6</sub> H <sub>4</sub>	<b>2f</b>	79	6 : 4 <sup>c)</sup>
7	<b>1g</b>	Cl	Ph	<b>2g</b>	77	5 : 5 <sup>c)</sup>

<sup>a)</sup> Yields of isolated products. <sup>b)</sup> Approximate ratios. <sup>c)</sup> Separable by CC (SiO<sub>2</sub>). <sup>d)</sup> An inseparable mixture.

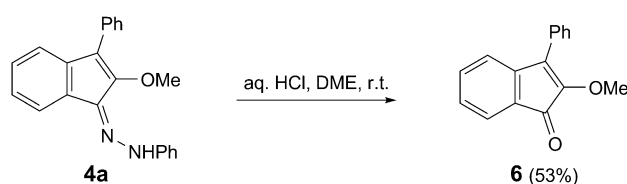
The progress of the hydrazone formation was monitored by the disappearance of the IR absorption band of the C=O group of **2a**. Subsequently, the resulting solution of the corresponding hydrazone **3a** was allowed to react with 1 equiv. of conc. HI at the same temperature for 1 h. Aqueous workup, followed by purification by CC on SiO<sub>2</sub> gave 2-methoxy-3-phenylinden-1-one (*Z*)-phenylhydrazone (**4a**) in 34% yield as a red viscous oil (Table 2, Entry 1) and not **5**. The structure was determined on the basis of the spectroscopic and analytical data given in the *Exper. Part*. The formation of 2-methoxy-3-phenylindenone (**6**) by acid hydrolysis further clarified the structure of **4a** (Scheme 2). Diagnostic NOE enhancements between the MeO H-atoms and the NH H-atom allowed unambiguous assignment of the configuration of **4a**. To improve the yield of **4a**, conc. HBr was used in place of conc. HI. The reaction proceeded much more cleanly to give **4a** in a rather improved yield, though it is still modest (Entry 2). The use of a smaller quantity of conc. HBr (0.5 equiv.) gave a poorer result (Entry 3). The reaction of (*E*)-**2a** with 1 equiv. of conc. HCl yielded only a trace amount of the desired product **4a** (Entry 4). We next examined the reaction of (*Z*)-**2a** with 1 equiv. of conc. HBr under the conditions mentioned above. Unfortunately, however, it resulted in the formation of a considerably intractable mixture of products, and only 24% yield of the desired product **4a** was obtained (Entry 5).

Table 2. Preparation of 3-Aryl-2-methoxy-1H-inden-1-one (*1Z*)-2-Phenylhydrazones **4**

Entry	<b>2</b>	Acid (conc.)	equiv.	<b>4</b>	R	Ar	Yield <sup>a)</sup> [%]
1	( <i>E</i> )- <b>2a</b>	HI	1	<b>4a</b>	H	Ph	34
2	( <i>E</i> )- <b>2a</b>	HBr	1	<b>4a</b>	H	Ph	50
3	( <i>E</i> )- <b>2a</b>	HBr	0.5	<b>4a</b>	H	Ph	29
4	( <i>E</i> )- <b>2a</b>	HCl	1	<b>4a</b>	H	Ph	< 1
5	( <i>Z</i> )- <b>2a</b>	HBr	1	<b>4a</b>	H	Ph	24
6	( <i>E</i> )- <b>2b</b>	HBr	1	<b>4b</b>	H	4-Me-C <sub>6</sub> H <sub>4</sub>	47
7	<b>2c</b>	HBr	1	<b>4c</b>	H	4-( <i>t</i> -Bu)-C <sub>6</sub> H <sub>4</sub>	31
8	( <i>E</i> )- <b>2d</b>	HBr	1	<b>4d</b>	H	4-Ph-C <sub>6</sub> H <sub>4</sub>	55
9	( <i>E</i> )- <b>2e</b>	HBr	1	<b>4e</b>	H	4-Cl-C <sub>6</sub> H <sub>4</sub>	54
10	( <i>E</i> )- <b>2f</b>	HBr	1	<b>4f</b>	H	3-MeO-C <sub>6</sub> H <sub>4</sub>	31
11	( <i>E</i> )- <b>2g</b>	HBr	1	<b>4g</b>	Cl	Ph	50

<sup>a)</sup> Yields of isolated products.

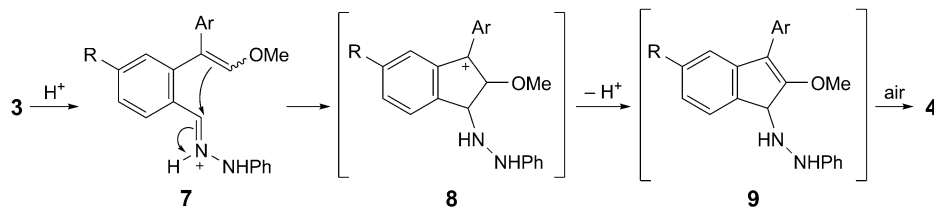
Scheme 2



The other six 2-(1-aryl-2-methoxyethenyl)benzaldehydes **2** were treated with conc. HBr under the conditions in *Entry 2* (see *Exper. Part*). Compounds (*E*)-**2b**, **2d**, **2e**, and **2g** gave the desired products **4b**, **4d**, **4e**, and **4g**, respectively, in yields comparable to that of **4a** (*Entries 6, 8, 9, and 11*), while the yield of **4f** was lower than those of the others (*Entry 10*). The use of a mixture (*E*)-**2c**/*Z*)-**2c** provided a poor result (*Entry 7*). Although 4-chloro-2-(2-methoxy-1-phenylethenyl)benzaldehyde (**2g**) could be successfully used in the present transformation to provide the corresponding desired product **4g** in a comparable yield (*Entry 11*), 4-methoxy-2-(2-methoxy-1-phenylethenyl)benzaldehyde failed to give the desired product (data not shown). The reaction of the hydrazone derived from this aldehyde with conc. HBr under the same conditions resulted in the formation of an intractable mixture of products. While the details are presently unclear, we would attribute this result and the lower yields of **4f** to the liability of the MeO substituents on the benzene nuclei to ether cleavage by HBr.

The formation of 3-aryl-2-methoxyinden-1-one (*Z*)-phenylhydrazones **4** from 2-(1-aryl-2-methoxyethenyl)benzaldehyde phenylhydrazones **3** is assumed to proceed *via* the intermediates depicted in *Scheme 3*. The hydrazones **3** are protonated to give the iminium ion intermediates **7**, which undergo intramolecular cyclization by the attack of the alkene C-atom adjacent to the MeO substituent on the iminium C-atom to form the stabilized bis-benzyl cation intermediates **8**. In each of the intermediates **7**, the attack of the most nucleophilic center, the C-atom  $\beta$  to the MeO substituent, on the iminium C-atom did not occur, because the formation of a four-membered ring is energetically disfavored. Deprotonation from **8** gives 1-hydrazinoindene intermediates **9**, which are

Scheme 3



then oxidized with air to give rise to **4**. The electron-withdrawing Cl substituent did not affect the yield of the products; the substrates (*E*)-**2e** and (*E*)-**2g** gave the products **4e** and **4g**, respectively, in the yields comparable to those of others (Entries 9 and 11, resp.).

In conclusion, we have shown that conc. HBr can mediate the formation of 3-aryl-2-methoxyinden-1-one (*Z*)-phenylhydrazones **4** from the respective phenylhydrazones **3**, derived from 2-(1-aryl-2-methoxyethenyl)benzaldehydes **2** and PhNHNH<sub>2</sub>, in moderate yields from (*E*)-**2** and in low yields from (*Z*)-**2**. Further studies are under way in our laboratory, to develop methods for the preparation of heterocyclic compounds utilizing **2**.

### Experimental Part

*General.* All of the org. solvents used in this study were dried over appropriate drying agents and distilled prior to use. TLC: silica gel 60 PF<sub>254</sub> (SiO<sub>2</sub>; Merck). Column chromatography (CC): Wako Gel C-200E. M.p.: Laboratory Devices MEL-TEMP II melting-point apparatus; uncorrected. IR Spectra: Shimadzu FTIR-8300 spectrophotometer;  $\tilde{\nu}$  in cm<sup>-1</sup>. NMR Spectra: JEOL ECP500 FT NMR spectrometer (<sup>1</sup>H: 500 and <sup>13</sup>C: 125 MHz), JEOL LA400 FT NMR spectrometer (<sup>1</sup>H: 400 and <sup>13</sup>C: 100 MHz); in CDCl<sub>3</sub>;  $\delta$  in ppm rel. to Me<sub>4</sub>Si as internal standard, *J* in Hz. LR-EI-MS (70 eV): JEOL JMS AX505 HA spectrometer; in *m/z*.

1-(1-Aryl-2-methoxyethenyl)-2-bromobenzenes **1a** [4], **1b** [2], **1c** [4], **1d** [2], **1e** [4], and **1f** [2] were prepared by appropriate reported procedures. BuLi was supplied by Asia Lithium Corporation. All other chemicals used in this study were commercially available.

1-Bromo-4-chloro-2-(2-methoxy-1-phenylethenyl)benzene (**1g**) was prepared from 2-bromo-5-chlorobenzaldehyde as described in [2]. The reaction of PhMgBr with 2-bromo-5-chlorobenzaldehyde gave (2-bromo-5-chlorophenyl)phenylmethanol. Yield: 92%. Colorless oil. *R*<sub>f</sub> (AcOEt/hexane 1:10) 0.29. IR (neat): 3310. <sup>1</sup>H-NMR (500 MHz): 2.83 (*s*, 1 H); 6.02 (*s*, 1 H); 7.08 (*dt*, *J* = 8.6, 2.9, 1 H); 7.24–7.34 (*m*, 5 H); 7.39 (*dd*, *J* = 8.6, 2.9, 1 H); 7.61 (*t*, *J* = 2.9, 1 H). Anal. calc. for C<sub>13</sub>H<sub>10</sub>BrClO (297.57): C 52.47, H 3.39; found: C 52.31, H 3.42. The pyridinium chlorochromate (PCC) oxidation of this alcohol gave (2-bromo-5-chlorophenyl)phenylmethanone. Yield: 91%. White solid. M.p. 89–91° (hexane/Et<sub>2</sub>O). IR (KBr): 1642. <sup>1</sup>H-NMR (500 MHz): 7.32–7.34 (*m*, 2 H); 7.48 (*t*, *J* = 7.4, 2 H); 7.57 (*d*, *J* = 8.0, 1 H); 7.63 (*t*, *J* = 7.4, 1 H); 7.80 (*d*, *J* = 7.4, 2 H). Anal. calc. for C<sub>13</sub>H<sub>8</sub>BrClO (295.56): C 52.83, H 2.73; found: C 52.88, H 2.72. This ketone was allowed to react with (methoxymethyl)triphenylphosphorane to give (*E*)-**1g**/*Z*)-**1g**. Yield: 68% (ca. 1:1).

*Data of (E)-1g.* Colorless oil. *R*<sub>f</sub> (AcOEt/hexane 1:20) 0.51. IR (neat): 1638. <sup>1</sup>H-NMR (500 MHz): 3.82 (*s*, 3 H); 6.26 (*s*, 1 H); 7.15–7.19 (*m*, 2 H); 7.26–7.36 (*m*, 5 H); 7.50 (*d*, *J* = 8.6, 1 H). Anal. calc. for C<sub>15</sub>H<sub>12</sub>BrClO (323.61): C 55.67, H 3.74; found: C 55.54, H 4.01.

*Data of (Z)-1g.* Colorless oil. *R*<sub>f</sub> (AcOEt/hexane 1:20) 0.43. IR (neat): 1634. <sup>1</sup>H-NMR (500 MHz): 3.76 (*s*, 3 H); 6.66 (*s*, 1 H); 7.09 (*d*, *J* = 8.0, 2 H); 7.15 (*dd*, *J* = 8.6, 2.2, 1 H); 7.19 (*t*, *J* = 7.4, 1 H); 7.23–7.27 (*m*, 3 H); 7.56 (*d*, *J* = 8.6, 1 H). Anal. calc. for C<sub>15</sub>H<sub>12</sub>BrClO (323.61): C 55.67, H 3.74; found: C 55.42, H 3.92.

2-(2-Methoxy-1-phenylethenyl)benzaldehyde (**2a**). *Representative Procedure.* To a stirred soln. of **1a** (1.7 g, 5.9 mmol) in THF (12 ml) at  $-78^{\circ}$  was added BuLi (1.6M soln. in hexane; 5.9 mmol) dropwise. After 1 h, 1-formylpiperidine (0.80 g, 7.1 mmol) was added, and the temp. was gradually raised to  $0^{\circ}$ . The reaction was quenched by adding sat. aq.  $\text{NH}_4\text{Cl}$  (15 ml), and the mixture was extracted with  $\text{Et}_2\text{O}$  ( $3 \times 15$  ml). The combined extracts were washed with brine, dried ( $\text{Na}_2\text{SO}_4$ ), and concentrated by evaporation. The residue was purified by CC ( $\text{SiO}_2$ ) to give (*E*)-**2a** (0.56 g, 41%) and (*Z*)-**2a** (0.54 g, 38%).

*Data of (E)-2a.* Pale-yellow oil.  $R_f$  (THF/hexane 1:15) 0.39. IR (neat): 2839, 2747, 1694, 1640.  $^1\text{H-NMR}$  (500 MHz): 3.84 (s, 3 H); 6.20 (s, 1 H); 7.19 (t,  $J = 7.3$ , 1 H); 7.29 (dd,  $J = 7.8$ , 7.3, 2 H); 7.33 (d,  $J = 7.8$ , 1 H); 7.39 (d,  $J = 7.8$ , 2 H); 7.44 (dd,  $J = 7.8$ , 7.3, 1 H); 7.56 (ddd,  $J = 7.8$ , 7.3, 1.4, 1 H); 7.96 (d,  $J = 7.8$ , 1 H); 10.09 (s, 1 H). Anal. calc. for  $\text{C}_{16}\text{H}_{14}\text{O}_2$  (238.28): C 80.65, H 5.92; found: C 80.64, H 5.92.

*Data of (Z)-2a.* Pale-yellow oil.  $R_f$  (THF/hexane 1:15) 0.27. IR (neat): 2842, 2749, 1694, 1632.  $^1\text{H-NMR}$  (500 MHz): 3.71 (s, 3 H); 6.78 (s, 1 H); 7.15 (dd,  $J = 7.8$ , 1.4, 2 H); 7.22–7.29 (m, 4 H); 7.43 (dd,  $J = 7.8$ , 7.3, 1 H); 7.58 (ddd,  $J = 7.8$ , 7.3, 1.4, 1 H); 7.99 (d,  $J = 7.8$ , 1 H); 10.07 (s, 1 H). Anal. calc. for  $\text{C}_{16}\text{H}_{14}\text{O}_2$  (238.28): C 80.65, H 5.92; found: C 80.60, H 5.90.

2-[2-Methoxy-1-(4-methylphenyl)ethenyl]benzaldehyde (**2b**). *Data of (E)-2b.* Yellow oil.  $R_f$  (THF/hexane 1:15) 0.31. IR (neat): 2842, 2749, 1694, 1628.  $^1\text{H-NMR}$  (500 MHz): 2.32 (s, 3 H); 3.82 (s, 3 H); 6.16 (s, 1 H); 7.10 (d,  $J = 8.2$ , 2 H); 7.28 (d,  $J = 8.2$ , 2 H); 7.31 (d,  $J = 7.8$ , 1 H); 7.42 (dd,  $J = 7.8$ , 7.3, 1 H); 7.55 (ddd,  $J = 7.8$ , 7.3, 1.4, 1 H); 7.95 (d,  $J = 7.8$ , 1 H); 10.08 (s, 1 H). Anal. calc. for  $\text{C}_{17}\text{H}_{16}\text{O}_2$  (252.31): C 80.93, H 6.39; found: C 80.83, H 6.41.

*Data of (Z)-2b.* Yellow oil.  $R_f$  (THF/hexane 1:15) 0.22. IR (neat): 2839, 2747, 1694, 1636.  $^1\text{H-NMR}$  (500 MHz): 2.32 (s, 3 H); 3.69 (s, 3 H); 6.74 (s, 1 H); 7.04 (d,  $J = 8.2$ , 2 H); 7.09 (d,  $J = 8.2$ , 2 H); 7.22 (d,  $J = 7.8$ , 1 H); 7.42 (dd,  $J = 7.8$ , 7.3, 1 H); 7.57 (ddd,  $J = 7.8$ , 7.3, 0.9, 1 H); 7.99 (d,  $J = 7.8$ , 1 H); 10.06 (s, 1 H). Anal. calc. for  $\text{C}_{17}\text{H}_{16}\text{O}_2$  (252.31): C 80.93, H 6.39; found: C 80.80, H 6.41.

2-[1-[4-(1,1-Dimethylethyl)phenyl]-2-methoxyethenyl]benzaldehyde (**2c**). Yellow oil. A mixture of stereoisomers (ca. 1:1).  $R_f$  (THF/hexane 1:15) 0.43. IR (neat): 2839, 2742, 1694, 1634.  $^1\text{H-NMR}$  (500 MHz): 1.295 (s, 4.5 H); 1.301 (s, 4.5 H); 3.69 (s, 1.5 H); 3.83 (s, 1.5 H); 6.16 (s, 0.5 H); 6.76 (s, 0.5 H); 7.08 (d,  $J = 8.7$ , 1 H); 7.24 (d,  $J = 7.8$ , 0.5 H); 7.28–7.34 (m, 3.5 H); 7.41–7.45 (m, 1 H); 7.55 (ddd,  $J = 7.8$ , 7.3, 1.4, 0.5 H); 7.58 (ddd,  $J = 7.8$ , 7.3, 1.4, 0.5 H); 7.96 (dd,  $J = 7.8$ , 1.4, 0.5 H); 7.99 (dd,  $J = 7.8$ , 1.4, 0.5 H); 10.06 (s, 0.5 H); 10.09 (s, 0.5 H). Anal. calc. for  $\text{C}_{20}\text{H}_{22}\text{O}_2$  (294.39): C 81.60, H 7.53; found: C 81.59, H 7.52.

(*E*)-2-[1-(1,1'-Biphenyl-4-yl)-2-methoxyethenyl]benzaldehyde (**2d**). Yellow oil.  $R_f$  (THF/hexane 1:15) 0.39. IR (neat): 2839, 2746, 1692, 1622.  $^1\text{H-NMR}$  (500 MHz): 3.87 (s, 3 H); 6.24 (s, 1 H); 7.33 (tt,  $J = 7.3$ , 1.4, 1 H); 7.37 (dd,  $J = 7.8$ , 1.4, 1 H); 7.40–7.49 (m, 5 H); 7.53 (d,  $J = 8.7$ , 2 H); 7.56–7.60 (m, 3 H); 7.98 (dd,  $J = 7.8$ , 1.4, 1 H); 10.13 (s, 1 H). Anal. calc. for  $\text{C}_{22}\text{H}_{18}\text{O}_2$  (314.38): C 84.05, H 5.77; found: C 84.07, H 5.82.

2-[1-(4-Chlorophenyl)-2-methoxyethenyl]benzaldehyde (**2e**). *Data of (E)-2e.* Yellow oil.  $R_f$  (AcOEt/hexane 1:10) 0.26. IR (neat): 2841, 2746, 1691, 1631.  $^1\text{H-NMR}$  (500 MHz): 3.85 (s, 3 H); 6.23 (s, 1 H); 7.26 (d,  $J = 8.6$ , 2 H); 7.31 (dd,  $J = 7.4$ , 1.1, 1 H); 7.33 (d,  $J = 8.6$ , 2 H); 7.46 (ddd,  $J = 8.0$ , 7.4, 1.1, 1 H); 7.58 (td,  $J = 7.4$ , 1.7, 1 H); 7.96 (dd,  $J = 8.0$ , 1.7, 1 H); 10.06 (s, 1 H). Anal. calc. for  $\text{C}_{16}\text{H}_{13}\text{ClO}_2$  (272.73): C 70.46, H 4.80; found: C 70.41, H 4.90.

*Data of (Z)-2e.* Yellow oil.  $R_f$  (AcOEt/hexane 1:10) 0.20. IR (neat) 2841, 2749, 1694, 1632.  $^1\text{H-NMR}$  (500 MHz): 3.72 (s, 3 H); 6.77 (s, 1 H); 7.07 (d,  $J = 7.2$ , 2 H); 7.19 (dd,  $J = 7.2$ , 1.0, 1 H); 7.23 (d,  $J = 7.2$ , 2 H); 7.44 (t,  $J = 6.3$ , 1 H); 7.59 (ddd,  $J = 7.2$ , 6.3, 1.0, 1 H); 8.00 (d,  $J = 6.8$ , 1.0, 1 H); 10.04 (s, 1 H). Anal. calc. for  $\text{C}_{16}\text{H}_{13}\text{ClO}_2$  (272.73): C 70.46, H 4.80; found: C 70.43, H 4.80.

2-[2-Methoxy-1-(3-methoxyphenyl)ethenyl]benzaldehyde (**2f**). *Data of (E)-2f.* Yellow oil.  $R_f$  (AcOEt/hexane 1:15) 0.31. IR (neat): 2839, 2746, 1694, 1631.  $^1\text{H-NMR}$  (500 MHz): 3.76 (s, 3 H); 3.84 (s, 3 H); 6.21 (s, 1 H); 6.75 (dd,  $J = 8.2$ , 2.3, 1 H); 6.91 (dd,  $J = 7.8$ , 1.4, 1 H); 7.04 (dd,  $J = 2.3$ , 1.8, 1 H); 7.21 (dd,  $J = 8.2$ , 7.8, 1 H); 7.33 (dd,  $J = 7.8$ , 0.9, 1 H); 7.43 (dd,  $J = 7.8$ , 7.3, 1 H); 7.55 (ddd,  $J = 7.8$ , 7.3, 1.4, 1 H); 7.96 (dd,  $J = 7.8$ , 0.9, 1 H); 10.08 (s, 1 H). Anal. calc. for  $\text{C}_{17}\text{H}_{16}\text{O}_3$  (268.31): C 76.10, H 6.01; found: C 75.93, H 6.06.

*Data of (Z)-2f.* Yellow oil.  $R_f$  (AcOEt/hexane 1:15) 0.21. IR (neat): 2839, 2745, 1694, 1634.  $^1\text{H-NMR}$  (500 MHz): 3.79 (s, 3 H); 3.82 (s, 3 H); 6.12 (s, 1 H); 6.83 (d,  $J = 8.7$ , 2 H); 7.31–7.34 (m, 3 H); 7.43 (dd,

$J = 7.8, 7.3, 1 \text{ H}$ ); 7.55 (*ddd*,  $J = 7.8, 7.3, 1.4, 1 \text{ H}$ ); 7.95 (*d*,  $J = 7.8, 1 \text{ H}$ ); 10.07 (*s*, 1 H). Anal. calc. for  $\text{C}_{17}\text{H}_{16}\text{O}_3$  (268.31): C 76.10, H 6.01; found: C 75.95, H 6.17.

**4-Chloro-2-(2-methoxy-1-phenylethynyl)benzaldehyde (2g)**. Data of (E)-**2g**. Yellow oil.  $R_f$  (AcOEt/hexane 1:10) 0.40. IR (neat): 2843, 2751, 1693, 1636.  $^1\text{H-NMR}$  (500 MHz): 3.85 (*s*, 3 H); 6.23 (*s*, 1 H); 7.21 (*t*,  $J = 7.4, 1 \text{ H}$ ); 7.31 (*t*,  $J = 7.4, 2 \text{ H}$ ); 7.32 (*d*,  $J = 1.7, 1 \text{ H}$ ); 7.37 (*d*,  $J = 7.4, 2 \text{ H}$ ); 7.40 (*dd*,  $J = 8.6, 1.7, 1 \text{ H}$ ); 7.89 (*d*,  $J = 8.6, 1 \text{ H}$ ); 10.01 (*s*, 1 H). Anal. calc. for  $\text{C}_{21}\text{H}_{15}\text{ClO}_2$  (272.73): C 70.46, H 4.80; found: C 70.19, H 4.86.

Data of (Z)-**2g**. Yellow oil.  $R_f$  (AcOEt/hexane 1:10) 0.33. IR (neat): 2843, 2754, 1693, 1636.  $^1\text{H-NMR}$  (500 MHz): 3.72 (*s*, 3 H); 6.78 (*s*, 1 H); 7.14 (*d*,  $J = 7.4, 2 \text{ H}$ ); 7.21–7.31 (*m*, 4 H); 7.39 (*d*,  $J = 8.0, 1 \text{ H}$ ); 7.93 (*d*,  $J = 8.0, 1 \text{ H}$ ); 9.99 (*s*, 1 H). Anal. calc. for  $\text{C}_{16}\text{H}_{13}\text{ClO}_2$  (272.73): C 70.46, H 4.80; found: C 70.40, H 4.85.

**2-Methoxy-3-phenyl-1H-inden-1-one (1Z)-2-Phenylhydrazone (4a)** Representative Procedure. To a stirred soln. of (E)-**2a** (0.36 g, 1.5 mmol) in MeCN (3 ml) at r.t. was added  $\text{PhNHNH}_2$  (0.16 g, 1.5 mmol), and stirring was continued overnight at the same temp. Then, conc. HBr (0.25 g, 1.5 mmol) was added, and the mixture was stirred for an additional 1 h at the same temp. Sat. aq.  $\text{NaHCO}_3$  (10 ml) was added, the mixture was extracted with AcOEt ( $3 \times 10 \text{ ml}$ ), and the combined extracts were washed with brine (10 ml) and dried ( $\text{Na}_2\text{SO}_4$ ). After evaporation of the solvent, the residue was purified by CC ( $\text{SiO}_2$ ) to give **4a** (0.24 g, 50%). Red viscous oil.  $R_f$  (benzene/hexane 1:3) 0.50. IR (neat): 3325, 1601.  $^1\text{H-NMR}$  (500 MHz): 3.61 (*s*, 3 H); 6.88 (*tt*,  $J = 7.3, 1.4, 1 \text{ H}$ ); 6.93–6.97 (*m*, 1 H); 7.05–7.10 (*m*, 2 H); 7.19 (*dd*,  $J = 7.8, 1.4, 2 \text{ H}$ ); 7.25 (*dd*,  $J = 7.8, 7.3, 2 \text{ H}$ ); 7.30 (*tt*,  $J = 7.3, 1.4, 1 \text{ H}$ ); 7.38 (*dd*,  $J = 7.8, 7.3, 2 \text{ H}$ ); 7.46 (*dd*,  $J = 7.8, 1.4, 2 \text{ H}$ ); 7.61–7.64 (*m*, 1 H); 10.52 (*s*, 1 H).  $^{13}\text{C-NMR}$  (125 MHz): 60.67; 113.33; 118.71; 118.84; 121.50; 123.47; 124.72; 127.16; 127.77; 128.41; 129.32; 129.45; 130.26; 133.42; 136.05; 139.59; 143.62; 149.09. MS: 326 (100,  $M^+$ ). Anal. calc. for  $\text{C}_{22}\text{H}_{18}\text{N}_2\text{O}$  (326.39): C 80.96, H 5.56, N 8.58; found: C 80.93, H 5.82, N 8.41.

**2-Methoxy-3-(4-methylphenyl)-1H-inden-1-one (1Z)-2-Phenylhydrazone (4b)**. Red solid. M.p. 132–134° (hexane/AcOEt). IR (KBr): 3322, 1603.  $^1\text{H-NMR}$  (400 MHz): 2.42 (*s*, 3 H); 3.71 (*s*, 3 H); 6.96 (*t*,  $J = 7.3, 1 \text{ H}$ ); 7.04–7.06 (*m*, 1 H); 7.13–7.16 (*m*, 2 H); 7.26–7.29 (*m*, 4 H); 7.33 (*dd*,  $J = 8.3, 7.3, 2 \text{ H}$ ); 7.44 (*d*,  $J = 8.3, 2 \text{ H}$ ); 7.68–7.70 (*m*, 1 H); 10.59 (*s*, 1 H).  $^{13}\text{C-NMR}$  (100 MHz): 21.37; 60.59; 113.30; 118.69; 118.90; 121.43; 123.83; 124.71; 127.14; 129.14; 129.28; 129.31; 130.31; 130.37; 136.20; 137.63; 139.64; 143.69; 149.01. MS: 340 (100,  $M^+$ ). Anal. calc. for  $\text{C}_{23}\text{H}_{20}\text{N}_2\text{O}$  (340.42): C 81.15, H 5.92, N 8.23; found: C 81.14, H 6.00, N 8.19.

**3-[4-(1,1-Dimethylethyl)phenyl]-2-methoxy-1H-inden-1-one (1Z)-2-Phenylhydrazone (4c)**. Beige oil.  $R_f$  (THF/hexane 1:15) 0.43. IR (neat): 3325, 1603.  $^1\text{H-NMR}$  (500 MHz): 1.31 (*s*, 9 H); 3.64 (*s*, 3 H); 6.89 (*t*,  $J = 7.3, 1 \text{ H}$ ); 7.00–7.03 (*m*, 1 H); 7.07–7.10 (*m*, 2 H); 7.18–7.20 (*m*, 3 H); 7.26 (*dd*,  $J = 7.8, 7.3, 1 \text{ H}$ ); 7.39–7.43 (*m*, 4 H); 7.61–7.64 (*m*, 1 H); 10.54 (*s*, 1 H).  $^{13}\text{C-NMR}$  (125 MHz): 14.07; 31.37; 50.67; 113.28; 118.66; 119.04; 121.40; 123.97; 124.69; 125.29; 127.11; 129.00; 129.30; 130.17; 130.39; 136.26; 139.59; 143.67; 148.99; 150.81. MS: 382 (100,  $M^+$ ). Anal. calc. for  $\text{C}_{26}\text{H}_{26}\text{N}_2\text{O}$  (382.50): C 81.64, H 6.85, N 7.32; found: C 81.41, H 7.02, N 7.23.

**3-(1,1'-Biphenyl-4-yl)-2-methoxy-1H-inden-1-one (1Z)-2-Phenylhydrazone (4d)**. Red solid. M.p. 156–157° (hexane). IR (KBr): 3321, 1601.  $^1\text{H-NMR}$  (500 MHz): 3.77 (*s*, 3 H); 6.98 (*t*,  $J = 7.3, 1 \text{ H}$ ); 7.12–7.14 (*m*, 1 H); 7.17–7.20 (*m*, 2 H); 7.28 (*dd*,  $J = 7.8, 1.4, 2 \text{ H}$ ); 7.35 (*t*,  $J = 7.3, 2 \text{ H}$ ); 7.39 (*t*,  $J = 7.3, 1 \text{ H}$ ); 7.49 (*dd*,  $J = 7.8, 7.3, 2 \text{ H}$ ); 7.64 (*d*,  $J = 8.2, 2 \text{ H}$ ); 7.68 (*dd*,  $J = 7.8, 1.4, 2 \text{ H}$ ); 7.70–7.73 (*m*, 3 H); 10.63 (*s*, 1 H).  $^{13}\text{C-NMR}$  (125 MHz): 60.80; 113.36; 118.77; 118.94; 121.56; 123.43; 124.83; 127.01; 127.07; 127.20; 127.52; 128.88 (two overlapped C-atoms); 129.34; 129.82; 130.38; 132.35; 136.08; 139.37; 140.53; 143.62; 149.27. MS: 402 (100,  $M^+$ ). Anal. calc. for  $\text{C}_{28}\text{H}_{22}\text{N}_2\text{O}$  (402.49): C 83.56, H 5.51, N 6.96; found: C 83.27, H 5.61, N 6.82.

**3-(4-Chlorophenyl)-2-methoxy-1H-inden-1-one (1Z)-2-Phenylhydrazone (4e)**. Red viscous oil.  $R_f$  (AcOEt/hexane 1:10) 0.71. IR (neat): 3323, 1603.  $^1\text{H-NMR}$  (400 MHz): 3.71 (*s*, 3 H); 6.96–7.01 (*m*, 2 H); 7.16–7.18 (*m*, 2 H); 7.27 (*d*,  $J = 7.4, 2 \text{ H}$ ); 7.34 (*t*,  $J = 7.4, 2 \text{ H}$ ); 7.44 (*d*,  $J = 8.0, 2 \text{ H}$ ); 7.49 (*d*,  $J = 8.0, 2 \text{ H}$ ); 7.70–7.71 (*m*, 1 H); 10.59 (*s*, 1 H).  $^{13}\text{C-NMR}$  (125 MHz): 60.77; 113.40; 118.64; 118.83; 121.71; 122.32; 124.93; 127.22; 128.75; 129.35; 130.20; 130.58; 130.74; 131.90; 135.72; 139.04; 143.51; 149.34. MS: 360 (100,  $M^+$ ). Anal. calc. for  $\text{C}_{22}\text{H}_{17}\text{ClN}_2\text{O}$  (360.84): C 73.23, H 4.75, N 7.96; found: C 73.16, H 4.82, N 7.73.

2-Methoxy-3-(3-methoxyphenyl)-1H-inden-1-one (1Z)-2-Phenylhydrazone (**4f**). Red viscous oil.  $R_f$  (AcOEt/hexane 1:10) 0.61. IR (neat): 3323, 1601.  $^1\text{H-NMR}$  (400 MHz): 3.73 (s, 3 H); 3.88 (s, 3 H); 6.91–6.98 (m, 2 H); 7.04–7.17 (m, 5 H); 7.24–7.28 (m, 2 H); 7.33 (dd,  $J = 7.8, 7.3$ , 2 H); 7.38 (d,  $J = 7.8$ , 1 H); 7.68–7.72 (m, 1 H); 10.60 (s, 1 H).  $^{13}\text{C-NMR}$  (100 MHz): 55.29; 60.60; 113.34; 113.50; 114.81; 118.71; 118.88; 121.53; 122.00; 123.28; 124.72; 127.19; 129.32; 129.44; 130.21; 134.75; 135.99; 139.53; 143.62; 149.09; 159.56. MS: 356 (100,  $M^+$ ). Anal. calc. for  $\text{C}_{25}\text{H}_{20}\text{N}_2\text{O}_2$  (356.42): C 77.51, H 5.66, N 7.86; found: C 77.40, H 5.81, N 7.62.

5-Chloro-2-methoxy-3-phenyl-1H-inden-1-one (1Z)-2-Phenylhydrazone (**4g**). Red solid. M.p. 92–95° (hexane). IR (KBr): 3322, 1601.  $^1\text{H-NMR}$  (500 MHz): 3.72 (s, 3 H); 6.96 (s, 1 H); 6.99 (t,  $J = 7.4$ , 1 H); 7.11 (d,  $J = 8.0$ , 1 H); 7.27 (d,  $J = 7.4$ , 2 H); 7.34 (t,  $J = 7.4$ , 2 H); 7.40 (t,  $J = 7.4$ , 1 H); 7.44–7.54 (m, 3 H); 7.60 (d,  $J = 8.0$ , 1 H); 7.79 (d,  $J = 8.0$ , 1 H); 10.61 (s, 1 H).  $^{13}\text{C-NMR}$  (100 MHz): 60.79; 113.47; 119.04; 119.65; 121.88; 124.34; 128.02; 128.30; 128.45; 128.55; 129.37; 129.52; 130.00; 132.88; 132.96; 134.82; 143.35; 149.83. MS: 360 (100,  $M^+$ ). Anal. calc. for  $\text{C}_{22}\text{H}_{17}\text{ClN}_2\text{O}$  (360.84): C 73.23, H 4.75, N 7.76; found: C 73.15, H 4.80, N 7.65.

2-Methoxy-3-phenyl-1H-inden-1-one (**6**) [5]. To a stirred soln. of **4a** (30 mg, 0.090 mmol) in 1,2-dimethoxyethane (2 ml) at r.t. was added 10% aq. HCl (1 ml). After stirring the mixture overnight at the same temp., sat. aq.  $\text{NaHCO}_3$  (10 ml) was added. The org. materials were extracted with AcOEt ( $3 \times 5$  ml), and the combined extracts were washed with brine (10 ml) and dried ( $\text{Na}_2\text{SO}_4$ ). After evaporation of the solvent, the residue was purified by prep. TLC ( $\text{SiO}_2$ ) to give **6** (12 mg, 53%). Orange solid. M.p. 68–69° (hexane/ $\text{Et}_2\text{O}$ ) ([5]: m.p. 67–68°). IR (neat): 1713, 1610.  $^1\text{H-NMR}$  (500 MHz): 3.96 (s, 3 H); 7.00 (d,  $J = 7.4$ , 1 H); 7.10 (t,  $J = 7.4$ , 1 H); 7.26 (td,  $J = 7.4, 1.1$ , 1 H); 7.36 (d,  $J = 7.4$ , 1 H); 7.41 (tt,  $J = 7.4, 1.1$ , 1 H); 7.48 (t,  $J = 7.4$ , 2 H); 7.59 (dd,  $J = 7.4, 1.1, 2$  H).

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