Synthesis of 2-Sulfonylindenones by Green-light-mediated Addition of Sulfur-Centered Radicals to 1, 3-Diarylpropynones

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A. General Information

NMR spectra were performed on a Bruker Avance III 400 spectrometer (\(^1\)H: 400 MHz; \(^13\)C: 100 MHz). \(^1\)H NMR chemical shifts were determined relative to Me\(_4\)Si (0.0 ppm) as an internal standard. \(^13\)C NMR chemical shifts were determined relative to CDCl\(_3\) (77.0 ppm). HRMS date were determined on a Bruker Daltonics APEXII 47e FT-ICR spectrometer. Mass spectra were recorded by the EI method on a HP 5998 mass spectrometer. Melting points are uncorrected.

B. Characterization data

3-Phenyl-2-(phenylthio)-1\(^H\)-inden-1-one(3a).
Red solid, m.p. 120-125\(^\circ\)C(lit.\(^1\) 125–127\(^\circ\)C);\(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.61\text{-}7.59\) (m, 2H), 7.58–7.49 (m, 4H), 7.43–7.31 (m, 1H), 7.30-7.25 (m, 3H), 7.22–7.18 (m, 3H), 7.16–7.11 (m, 1H); \(^13\)C NMR (100 MHz, CDCl\(_3\)): \(\delta =193.14, 161.84, 144.42, 134.70, 133.67, 131.71, 131.01, 129.39, 129.23, 128.93, 128.56, 128.51, 127.25, 126.43, 123.44, 121.65\); HRMS (ESI) calcd for C\(_{21}\)H\(_{15}\)O\(_S\) (M\(^+\)+H): 315.0838, Found: 315.0836.

7-Methoxy-3-phenyl-2-(phenylthio)-1\(^H\)-inden-1-one(3b).
Red solid, m.p. 130-132\(^\circ\)C(lit.\(^2\) 128–130\(^\circ\)C);\(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.59\text{-}7.53\) (m, 2H), 7.51-7.40 (m, 3H), 7.37-7.32 (m, 1H), 7.31-7.23 (m, 2H), 7.21-7.07 (m, 3H), 6.89 (d, \(J = 8.6\) Hz, 1H), 6.81 (d, \(J = 7.8\) Hz, 1H), 3.98 (s, 3H); \(^13\)C NMR (100 MHz, CDCl\(_3\)): \(\delta =187.69, 159.66, 156.91, 156.89, 135.70, 135.64, 134.74, 131.80, 131.76, 129.75, 129.25, 128.79, 128.58, 128.35, 126.22, 115.05, 114.63, 56.04\); HRMS (ESI) calcd for C\(_{22}\)H\(_{17}\)O\(_2\)S (M\(^+\)+H): 345.0944, Found: 345.0940.

7-Fluoro-3-phenyl-2-(phenylthio)-1\(^H\)-inden-1-one(3c).
Red solid, m.p. 140-142\(^\circ\)C(lit.\(^2\) 138–140\(^\circ\)C);\(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.63\text{-}7.44\) (m, 5H), 7.43-7.33 (m, 1H), 7.32-7.07 (m, 5H), 7.04-6.89 (m, 2H); \(^13\)C NMR (100 MHz, CDCl\(_3\)): \(\delta =189.05, 160.26, 160.19, 159.56, 156.04, 146.33, 136.07(d, \(^3\)JCF = 11.4 Hz), 133.89, 131.32, 131.09, 129.59, 128.91, 128.53, 128.46, 126.66, 118.60(d, \(^3\)JCF = 28.5 Hz), 117.99; HRMS (ESI) calcd for C\(_{21}\)H\(_{14}\)FOS (M\(^+\)+H): 333.0744, Found: 333.0751.

7-Chloro-3-phenyl-2-(phenylthio)-1\(^H\)-inden-1-one(3d).
Red solid, m.p. 120-123\(^\circ\)C;\(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.63\text{-}7.49\) (m, 5H), 7.42 (d, \(J = 8.4\) Hz, 1H), 7.28-7.13 (m, 5H), 7.12-7.04 (m, 2H); \(^13\)C NMR (100 MHz, CDCl\(_3\)): \(\delta =189.76, 158.55, 149.18, 138.55, 133.82, 133.45, 130.57, 129.86, 129.50, 129.36, 128.59, 128.18, 128.09, 127.46, 126.18, 120.27, 117.18; HRMS (ESI) calcd for C\(_{21}\)H\(_{14}\)BrOS (M\(^+\)+H): 349.0448, Found: 349.0451.
7-Bromo-3-phenyl-2-(phenylthio)-1H-inden-1-one (3e).
Red solid, m.p. 120-123°C(lit.2 120–122°C); 1H NMR (400 MHz, CDCl3): δ =7.58-7.53 (m, 2H), 7.52-7.47 (m, 3H), 7.40 (d, J = 8.1 Hz, 1H), 7.32-7.28 (m, 2H), 7.26-7.18 (m, 3H), 7.17-7.10 (m, 2H); 13C NMR (100 MHz, CDCl3): δ =190.12, 159.36, 147.09, 134.36, 134.32, 134.00, 131.09, 130.37, 130.01, 129.88, 129.11, 128.70, 128.61, 127.94, 126.73, 120.82, 119.64; HRMS (ESI) calcd for C21H18BrOS (M+H): 392.9943, Found: 392.9950.

5-Methyl-3-phenyl-2-(phenylthio)-1H-inden-1-one (3f).
Red solid, m.p. 128-130°C(lit.1 130–132°C); 1H NMR (400 MHz, CDCl3): δ =7.63-7.59 (m, 2H), 7.56-7.51 (m, 3H), 7.46 (d, J = 7.5 Hz, 1H), 7.32-7.29 (m, 2H), 7.26-7.21 (m, 2H), 7.19-7.15 (m, 1H), 7.14-7.11 (m, 1H), 7.04 (s, 1H), 2.32 (s, 3H); 13C NMR (100 MHz, CDCl3): δ =192.75, 161.64, 144.79, 144.68, 134.84, 131.79, 130.01, 129.34, 129.08, 128.86, 128.53, 128.49, 128.47, 128.52, 126.30, 123.49, 122.86, 22.10; HRMS (ESI) calcd for C22H17OS (M+H): 329.0995, Found: 329.0993.

5-Fluoro-3-phenyl-2-(phenylthio)-1H-inden-1-one (3g).
Red solid, m.p. 160-162°C(lit.1 159–161°C); 1H NMR (400 MHz, CDCl3): δ =7.59-7.56 (m, 2H), 7.53-7.45 (m, 4H), 7.29-7.27 (m, 2H), 7.21-7.18 (m, 2H), 7.16-7.12 (m, 1H), 6.94-6.89 (m, 2H); 13C NMR (100 MHz, CDCl3): δ =191.14, 167.48, 165.45, 158.52, 147.69, 134.13, 131.47, 130.24, 129.73, 128.89, 128.64, 128.33, 126.73, 125.24, 125.13, 114.68 (d, JCF = 21.5 Hz), 110.33 (d, JCF = 22.6 Hz); HRMS (ESI) calcd for C21H16FOS (M+H): 333.0744, Found: 333.0740.

5-Chloro-3-phenyl-2-(phenylthio)-1H-inden-1-one (3h).
Red solid, m.p. 152-154°C(lit.1 151–153°C); 1H NMR (400 MHz, CDCl3): δ =7.59-7.56 (m, 2H), 7.53-7.47 (m, 3H), 7.43 (d, J = 7.8 Hz, 1H), 7.29-7.24 (m, 3H), 7.22-7.19 (m, 2H), 7.16-7.11 (m, 2H); 13C NMR (100 MHz, CDCl3): δ =191.49, 159.40, 146.28, 140.00, 133.78, 131.13, 130.31, 129.68, 129.06, 129.02, 128.90, 128.73, 128.66, 128.33, 126.73, 124.23, 122.13; HRMS (ESI) calcd for C21H16ClOS (M+H): 349.0448, Found: 333.0452.

5-Bromo-3-phenyl-2-(phenylthio)-1H-inden-1-one (3i).
Red solid, m.p. 140-142°C(lit.1 140–141°C); 1H NMR (400 MHz, CDCl3): δ =7.69-7.62 (m, 2H), 7.58 (d, J = 7.0 Hz, 1H), 7.55-7.51 (m, 2H), 7.47-7.40 (m, 1H), 7.36-7.29 (m, 3H), 7.25-7.21 (m, 3H), 7.19-7.14 (m, 1H); 13C NMR (100 MHz, CDCl3): δ =193.06, 161.82, 144.39, 134.65, 133.61, 131.69, 130.97, 130.14, 129.35, 129.21, 128.88, 128.47, 127.24, 126.40, 123.39, 121.60; HRMS (ESI) calcd for C21H16BrOS (M+H): 392.9943, Found: 392.9940.

5-Methoxy-3-phenyl-2-(phenylthio)-1H-inden-1-one (3j).
Red solid, m.p. 88-89°C(lit.2 84–86°C); 1H NMR (400 MHz, CDCl3): δ =7.84-7.76 (m, 4H), 7.49-7.40 (m, 3H), 7.31-7.23 (m, 4H), 6.88-6.82 (m, 2H), 3.88 (s, 3H); 13C NMR (100 MHz, CDCl3): δ =192.88, 163.19, 138.12, 134.73, 132.52, 131.98, 131.86, 131.41, 130.19, 129.09, 129.00, 128.84, 128.53, 128.38, 127.36, 113.77, 113.35, 55.41; HRMS (ESI) calcd for C22H17O2S (M+H): 345.0944, Found:345.0951.
2-(Phenylthio)-3-p-tolyl-1\(H\)-inden-1-one (3k).
Red solid, m.p. 108-110°C(lit.1 104–106°C); \(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.53–7.49\) (m, 3H), 7.41–7.35 (m, 1H), 7.32–7.27 (m, 4H), 7.25–7.19 (m, 4H), 7.18–7.10 (m, 1H), 2.45 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)):\(\delta =192.63, 162.00, 144.06, 140.31, 134.68, 133.18, 130.83, 129.01, 128.90, 128.69, 128.54, 128.49, 128.17, 126.21, 126.11, 122.92, 121.43, 21.55; HRMS (ESI) c地质 for C\(_{22}\)H\(_{17}\)OS (M\(^{+}\)H): 329.0995, Found: 329.0999.

3-(4-Methoxyphenyl)-2-(phenylthio)-1\(H\)-inden-1-one (3i).\(^2\)
Red oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.82-7.69\) (m, 3H), 7.50-7.41 (m, 1H), 7.40-7.30 (m, 2H), 7.29-7.19 (m, 2H), 7.18-7.03 (m, 3H), 6.91 (d, J = 8.2 Hz, 2H), 3.83-3.73 (m, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)):\(\delta =194.49, 60.64, 142.04, 137.63, 133.76, 132.43, 132.02, 131.91, 130.23, 130.11, 129.15, 128.78, 128.31, 127.91, 26.95, 126.76, 113.76, 55.46; HRMS (ESI) c地质 for C\(_{22}\)H\(_{17}\)OS (M\(^{+}\)H): 345.0944, Found: 345.0940.

3-(4-Ethylphenyl)-2-(phenylthio)-1\(H\)-inden-1-one (3m).\(^2\)
Red oil; \(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.82-7.69\) (m, 3H), 7.57-7.44 (m, 1H), 7.43-7.40 (m, 1H), 7.38-7.30 (m, 2H), 7.27-7.16 (m, 3H), 7.15-7.03 (m, 3H), 2.69 (q, J = 7.2 Hz, 2H), 1.64 (t, J = 7.3 Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)):\(\delta =194.22, 146.00, 140.85, 137.45, 134.01, 133.35, 132.01, 131.90, 130.29, 129.24, 128.81, 128.67, 128.49, 128.03, 127.99, 127.05, 28.86, 14.45; HRMS (ESI) c地质 for C\(_{22}\)H\(_{19}\)OS (M\(^{+}\)H): 343.1151, Found: 343.1159.

3-(4-Fluorophenyl)-2-(phenylthio)-1\(H\)-inden-1-one (3n).
Red solid, m.p. 131-135°C(lit.1 131–133°C); \(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.61-7.56\) (m, 2H), 7.53 (d, J = 6.8 Hz, 1H), 7.40-7.36 (m, 1H), 7.29-7.22 (m, 3H), 7.20-7.09 (m, 6H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)):\(\delta =193.54, 164.58\) (d, \(^{13}\)C\(_F\)=247 Hz), 160.11, 144.53, 136.98, 134.33, 133.45, 130.41, 130.13 (d, \(^{13}\)C\(_F\)=7.4Hz), 129.38, 129.20, 128.82, 128.65, 123.44, 120.78, 115.48 (d, \(^{13}\)C\(_F\)=15.2 Hz); HRMS (ESI) c地质 for C\(_{22}\)H\(_{19}\)FOS (M\(^{+}\)H): 333.0744, Found: 333.0751.

3-(4-Chlorophenyl)-2-(phenylthio)-1\(H\)-inden-1-one (3o).
Red solid, m.p. 84-86°C(lit.1 85–87°C); \(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.53-7.49\) (m, 3H), 7.48-7.44 (m, 2H), 7.41-7.32 (m, 1H), 7.30-7.24 (m, 3H), 7.21-7.18 (m, 2H), 7.16-7.11 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)):\(\delta =192.62, 159.67, 144.44, 136.77, 136.18, 134.33, 133.75, 131.56, 130.33, 129.86, 129.42, 128.73, 128.56, 128.01, 126.05, 122.42, 120.71; HRMS (ESI) c地质 for C\(_{22}\)H\(_{17}\)ClOS (M\(^{+}\)H): 349.0448, Found: 349.0451.

3-(4-Bromophenyl)-2-(phenylthio)-1\(H\)-inden-1-one (3p).
Red solid, m.p. 81-85°C; \(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.55-7.47\) (m, 3H), 7.46-7.43 (m, 2H), 7.41-7.34 (m, 1H), 7.26-7.21 (m, 3H), 7.17-7.06 (m, 4H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)):\(\delta =192.98, 160.07, 144.47, 136.99, 136.31, 134.09, 133.91, 130.87, 129.85, 129.13, 128.85, 128.51, 127.84, 126.53, 125.38, 123.67, 121.40; HRMS (ESI) c地质 for C\(_{22}\)H\(_{17}\)BrOS (M\(^{+}\)H): 392.9943, Found: 392.9951.

2-(Phenylthio)-3-o-tolyl-1\(H\)-inden-1-one (3q).
Red solid, m.p. 123-125°C(lit.1 125–127°C); \(^1\)H NMR (400 MHz, CDCl\(_3\)):\(\delta =7.53-7.49\) (m,
1H), 7.33−7.31 (m, 2H), 7.29−7.24 (m, 5H), 7.20−7.09 (m, 4H), 6.79 (d, J = 6.8 Hz, 2H), 2.28 (s, 3H); 13C NMR (100 MHz, CDCl3): δ =193.11, 162.04, 145.52, 135.99, 134.15, 133.79, 131.92, 130.77, 130.63, 130.43, 129.70, 129.46, 129.37, 128.98, 128.07, 126.94, 126.04, 126.41, 121.50, 20.86; HRMS (ESI) calcd for C22H13OS (M+H): 329.0995, Found: 329.0998.

3-Phenyl-2-(p-tolylthio)-1H-inden-1-one (4a).

Red solid, m.p. 150−153°C (lit.1 154−156°C); 1H NMR (400 MHz, CDCl3): δ = 7.59 (d, J = 6.8 Hz, 2H), 7.53−7.47 (m, 4H), 7.39−7.34 (m, 1H), 7.29−7.24 (m, 1H), 7.23−7.15 (m, 3H), 7.03 (d, J = 7.0 Hz, 2H), 2.28 (s, 3H); 13C NMR (100 MHz, CDCl3): δ =193.63, 161.82, 145.37, 137.14, 134.23, 132.41, 131.89, 131.34, 130.67, 130.43, 130.32, 129.84, 129.13, 129.13, 128.47, 124.07, 122.23, 21.85; HRMS (ESI) calcd for C22H13OS (M+H): 329.0995, Found: 329.1003.

2-(4-Methoxyphenylthio)-3-phenyl-1H-inden-1-one (4b).

Red solid, m.p. 150−153°C (lit.1 154−156°C); 1H NMR (400 MHz, CDCl3): δ = 7.60−7.56 (m, 2H), 7.54−7.47 (m, 4H), 7.39−7.34 (m, 1H), 7.32−7.23 (m, 3H), 7.18 (d, J = 6.8 Hz, 1H), 6.77 (d, J = 7.5 Hz, 2H), 3.78 (s, 3H); 13C NMR (100 MHz, CDCl3): δ =193.64, 159.76, 159.32, 144.62, 133.91, 132.88, 132.01, 131.14, 130.06, 129.29, 128.92, 128.76, 128.66, 124.21, 123.38, 121.61, 114.45, 55.65; HRMS (ESI) calcd for C22H13O3S (M+H): 345.0944, Found: 345.0951.

2-(4-Fluorophenylthio)-3-phenyl-1H-inden-1-one (4c).

Red solid, m.p. 150−153°C (lit.1 154−156°C); 1H NMR (400 MHz, CDCl3): δ = 7.60−7.56 (m, 2H), 7.53−7.47 (m, 4H), 7.40−7.36 (m, 1H), 7.31−7.26 (m, 3H), 7.19 (d, J = 7.5 Hz, 1H), 6.94−6.87 (m, 2H); 13C NMR (100 MHz, CDCl3): δ = 191.73, 161.26 (d, JCF = 109.25 Hz), 160.01, 144.09, 133.72, 132.36, 131.92, 130.91, 130.14, 129.45, 128.82, 128.63, 128.05, 127.96, 123.56, 121.72, 116.27 (d, JCF = 22.0 Hz); HRMS (ESI) calcd for C21H14FOS (M+H): 333.0744, Found: 333.0752.

2-(4-Chlorophenylthio)-3-phenyl-1H-inden-1-one (4d).

Red solid, m.p. 150−153°C (lit.1 154−156°C); 1H NMR (400 MHz, CDCl3): δ = 7.61−7.58 (m, 2H), 7.55−7.48 (m, 4H), 7.42−7.37 (m, 1H), 7.32−7.28 (m, 1H), 7.22−7.19 (m, 3H), 7.18−7.15 (m, 2H); 13C NMR (100 MHz, CDCl3): δ = 192.09, 162.01, 144.54, 134.04, 133.45, 132.87, 132.07, 131.26, 130.61, 130.20, 129.75, 129.27, 129.09, 128.64, 127.28, 123.84, 122.27; HRMS (ESI) calcd for C21H14ClOS (M+H): 349.0448, Found: 349.0451.

2-(4-Bromophenylthio)-3-phenyl-1H-inden-1-one (4e).

Red solid, m.p. 123−126°C; 1H NMR (400 MHz, CDCl3): δ = 7.54−7.46 (m, 2H), 7.40−7.32 (m, 4H), 7.29−7.26 (m, 1H), 7.25−7.11 (m, 6H); 13C NMR (100 MHz, CDCl3): δ = 194.45, 164.42, 144.26, 137.18, 134.15, 133.79, 133.33, 132.25, 130.74, 130.55, 127.21, 126.81, 126.16, 125.75, 125.29, 124.09, 122.46; HRMS (ESI) calcd for C21H14BrOS (M+H): 392.9943, Found: 392.9951.

2-(4-Nitrophenylthio)-3-phenyl-1H-inden-1-one (4f).

Yellow solid, m.p. 185−187°C (lit.1 187−189°C); 1H NMR (400 MHz, CDCl3): δ = 8.01 (d, J = 7.6 Hz, 2H), 7.56−7.44 (m, 6H), 7.40−7.28 (m, 2H), 7.25−7.16 (m, 3H); 13C NMR (100 MHz,
CDCl$_3$): $\delta$ = 193.18, 165.45, 146.36, 145.64, 144.44, 134.45, 131.64, 131.36, 130.54, 129.27, 128.91, 128.07, 126.91, 125.45, 125.01, 124.74, 122.73; HRMS (ESI) calcd for C$_{21}$H$_{14}$NO$_3$S (M$^+$+H): 360.0689, Found: 360.0692.

3-Phenyl-2-(o-tolylthio)-1H-inden-1-one (4g).
Red solid, m.p. 128-130°C; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ =7.52 (d, $J = 1.6$ Hz, 1H), 7.41–7.30 (m, 2H), 7.22–7.11 (m, 2H), 7.09–6.96 (m, 6H), 6.92–6.85 (m, 2H), 2.13 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ =194.34, 164.72, 141.82, 141.11, 138.17, 136.86, 135.22, 134.47, 133.99, 130.06, 129.29, 129.05, 128.51, 128.07, 127.97, 126.72, 126.34, 125.48, 124.31, 20.85; HRMS (ESI) calcd for C$_{22}$H$_{17}$O$_3$S (M$^+$+H): 329.0995, Found: 329.0990.

2-(2-Chlorophenylthio)-3-phenyl-1H-inden-1-one (4h).
Red solid, m.p. 155-158°C(lit. 156–158°C); $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ =7.56–7.49 (m, 3H), 7.48–7.40 (m, 3H), 7.38–7.33 (m, 1H), 7.29–7.22 (m, 2H), 7.18 (d, $J = 7.2$ Hz, 1H), 7.12–7.09 (m, 1H), 7.05–6.99 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ =192.48, 162.36, 144.12, 133.92, 133.59, 133.04, 131.36, 130.87, 130.18, 129.90, 129.62, 129.41, 128.46, 128.23, 127.11, 126.87, 125.77, 123.37, 121.64; HRMS (ESI) calcd for C$_{21}$H$_{14}$ClO$_3$S (M$^+$+H): 349.0448, Found: 349.0444.

C. Reference

[1] Zhang, X.S.; Jiao, J. Y.; Zhang, X. H.; Hu, B. L.; Zhang, X. G. Synthesis of 2-Sulfonylindenones via One-Pot Tandem Meyer–Schuster Rearrangement and Radical Cyclization of Arylpropynols with Disulfides. J. Org. Chem. 2016, 81, 5710-5716. DOI: 10.1021/acs.joc.6b00762.

[2] Zhou, J.; Zhang, G. L.; Zou, J. P.; Zhang, W. Synthesis of Phosphonylated and Thiolated Indenones by Manganese(III)-Mediated Addition of Phosphorus- and Sulfur-Centered Radicals to 1,3-Diarylpropynones. Eur. J. Org. Chem. 2011, 3412-3415. DOI: 10.1002/ejoc.201100486.

D. The LC-MS analysis of TEMPO-trapped complex
E. Copies of NMR spectra for compounds

3-Phenyl-2-(phenylthio)-1H-inden-1-one(3a)

$^1\text{H NMR: (400 MHz, CDCl}_3\text{)}$

$^{13}\text{C NMR: (100 MHz, CDCl}_3\text{)}$
7-methoxy-3-phenyl-2-(phenylthio)-1H-inden-1-one (3b)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
7-fluoro-3-phenyl-2-(phenylthio)-1H-inden-1-one (3c)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
7-chloro-3-phenyl-2-(phenylthio)-1H-inden-1-one(3d)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
7-bromo-3-phenyl-2-(phenylthio)-1H-inden-1-one(3e)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
5-methyl-3-phenyl-2-(phenylthio)-1H-inden-1-one (3f)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
5-fluoro-3-phenyl-2-(phenylthio)-1H-inden-1-one (3g)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
5-chloro-3-phenyl-2-(phenylthio)-1H-inden-1-one(3h)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
5-bromo-3-phenyl-2-(phenylthio)-1H-inden-1-one (3i)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
5-methoxy-3-phenyl-2-(phenylthio)-1H-inden-1-one(3j)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
2-(phenylthio)-3-(p-tolyl)-1H-inden-1-one (3k)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
3-(4-methoxyphenyl)-2-(phenylthio)-1H-inden-1-one (3l)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
3-(4-ethylphenyl)-2-(phenylthio)-1H-inden-1-one(3m)

${^1}H\text{ NMR: (400 MHz, CDCl}_3\text{)}$ 

![NMR spectrum](image)

${^{13}C\text{ NMR: (100 MHz, CDCl}_3\text{)}$ 

![NMR spectrum](image)
$3$-(4-fluorophenyl)-2-(phenylthio)-$^{1}H$-inden-1-one (3n)

$^{1}H$ NMR: (400 MHz, CDCl₃)

$^{13}C$ NMR: (100 MHz, CDCl₃)
3-(4-chlorophenyl)-2-(phenylthio)-1H-inden-1-one (3o)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
3-(4-bromophenyl)-2-(phenylthio)-1H-inden-1-one(3p)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
2-(phenylthio)-3-(o-toly)-1H-inden-1-one (3q)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
3-phenyl-2-(p-tolylthio)-1H-inden-1-one (4a)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
$2\text{-}((4\text{-methoxyphenyl})\text{thio})\text{-}3\text{-phenyl-}\text{1H\text{-}inden-1\text{-}one(4b)}$

$^1\text{H NMR: (400 MHz, CDCl}_3\text{)}$

$^1\text{C NMR: (100 MHz, CDCl}_3\text{)}$
2-((4-fluorophenyl)thio)-3-phenyl-1Hinden-1-one (4c)

$^{1}H$ NMR: (400 MHz, CDCl$_3$)

$^{13}C$ NMR: (100 MHz, CDCl$_3$)
$2'\text{-(4-chlorophenyl)thio)-3-phenyl-1H-inden-1-one(4d)}$

$^1\text{H NMR: (400 MHz, CDCl}_3\text{)}$

$^{13}\text{C NMR: (100 MHz, CDCl}_3\text{)}$
2-((4-bromophenyl)thio)-3-phenyl-1H-inden-1-one (4e)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
2-((4-nitrophenyl)thio)-3-phenyl-1H-inden-1-one(4f)

$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
$^1$H NMR: (400 MHz, CDCl$_3$)

$^{13}$C NMR: (100 MHz, CDCl$_3$)
2-((2-chlorophenyl)thio)-3-phenyl-1\(\text{H}\)-inden-1-one (4h)

\(^1\text{H}\) NMR: (400 MHz, CDCl\(_3\))

\(^{13}\text{C}\) NMR: (100 MHz, CDCl\(_3\))