Magnetically recyclable $\gamma$-Fe$_2$O$_3$–HAP nanoparticles for the cycloaddition reaction of alkynes, halides and azides in aqueous media

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1. Experimental

Preparation of the γ-Fe₂O₃/HAP nanoparticles catalyst

A solution of FeCl₂·4H₂O (3.7 mmol) and FeCl₃·6H₂O (7.4 mmol) was prepared by dissolving these salts in 100 ml distilled water under nitrogen atmosphere at room temperature. 25% of NH₄OH solution (20 ml) was then added with constant stirring. A black precipitate of γ-Fe₂O₃ was produced. Dropwise addition of NH₄OH helps to obtain small and uniform particle size. After 30 min, 200 ml of Ca(NO₃)₂·4H₂O (33.7 mmol) and (NH₄)₂HPO₄ (40 mmol) solution adjusted to pH=11 were added dropwise to the obtained precipitate for 1 h with vigorous stirring. The obtaining solution was then heated to 90 °C. After 2 h. the reaction mixture was cooled to room temperature and aged overnight. The dark brown precipitate was washed with distilled water. The synthesized catalyst was calcined at 300 °C for 3 h, yielding γ-Fe₂O₃/HAP (Fe content by ICP-AES: 1.093 mmol/g). The catalyst was characterized using various techniques such as XRD, FT-IR, ICP-AES, DSC-TGA, SEM and TEM.

General procedure for the synthesis of 1,2,3-triazoles

In a 10 ml round bottom flask fitted with a magnetic stirrer, the catalyst (5 mol % of Fe), phenyl acetylene (1 mmol), sodium azide (1.2 mmol) and benzyl bromide (1 mmol) were stirred in water (5 ml) at 100 °C for 5 h. The reaction progress was monitored by TLC. After 5 h, the reaction was quenched and the product was extracted with ethyl acetate. The organic layer was then separate out using separating funnel. The separated layer was washed with water and dried over sodium sulfate. The ethyl acetate solvent was removed using rotary evaporator, which left 94% pure desired product. The recovered catalyst was reused for further run without removing catalyst from the flask. All the prepared compounds were confirmed by GC-MS, IR, ¹H and ¹³C NMR.
2. Characterization of the $\gamma$-Fe$_2$O$_3$/HAP nanoparticles

![Fig.1 EDAX of $\gamma$-Fe$_2$O$_3$/HAP](image1)

The elemental analysis of the $\gamma$-Fe$_2$O$_3$/HAP was done by ICP-AES analysis technique. The ICP-AES analysis clearly shows presence of Fe metal ion.

![Fig.2 XRD of $\gamma$-Fe$_2$O$_3$/HAP](image2)
The XRD spectrum of γ-Fe$_2$O$_3$/HAP is depicted in Fig. 2. XRD of the γ-Fe$_2$O$_3$/HAP shows crystalline nature of the catalyst. The observed diffraction peaks agree well with that of the tetragonal structure of γ-Fe$_2$O$_3$.

**Fig. 3 SEM images of γ-Fe$_2$O$_3$/HAP**

The scanning electron micrograph of the γ-Fe$_2$O$_3$/HAP showed uniform particles size.

**Fig. 4 TEM images of γ-Fe$_2$O$_3$/HAP**
The characteristic absorption bands due to the bending vibration mode of O–P–O surface phosphate groups in the hydroxyapatite shell were observed at 570 and 602 cm\(^{-1}\) which were in overlap with Fe–O stretching. Also the stretching of P–O bond appeared at 1044 cm\(^{-1}\) overlapped with S–O stretching peak.
Nitrogen adsorption–desorption isotherms are shown in Fig. 6 and reveal that the adsorption–desorption process is not reversible. The surface area was calculated using BET method, and a value of 103 m$^2$ g$^{-1}$ was found for hydroxyapatite coated magnetic nanoparticle ($\gamma$-Fe$_2$O$_3$/HAP).
3. Characterization of compounds:

1-Benzyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM): oven rate (10 °C·min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (17.85 min); White solid, mp 126-128°C; IR (KBr): 694, 729, 768, 1049, 1076, 1223, 1358, 1466, 3121 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ: 5.23(2H, s, CH₂), 7.26-7.41(6H, m, Ar), 7.69(1H, s, CH), 7.79-7.82(4H, m, Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 54.1, 119.7, 125.7, 128, 128.2, 128.7, 128.8, 129.1, 130.6, 134.7, 148.1; MS: m/z (%): 235 (20), 207 (12), 206 (52), 180 (9), 179(7), 116 (100), 91 (98), 65 (30), 77 (5), 51 (10); Elemental analysis: found C 75.62, H 5.48, N 18.12, Calcd for C 75.59, H 5.53, N 17.87

1-(2-chlorobenzyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM): oven rate (10 °C·min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (19.17 min); White solid, mp 90-92°C; ¹H NMR (300 MHz, CDCl₃) δ: 5.67 (2H, s, N-CH₂), 7.16-7.46 (7H, m, 3H of Ar & 4H of Ar-Cl), 7.78 (1H, s, CH of triazole ring), 7.80-7.83 (2H, d, Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 51.36, 119.91, 125.64, 127.56, 128.14, 128.76, 129.83, 130.13, 130.15, 130.40, 132.49, 133.31, 147.99; MS: m/z (%): 269 (12), 240 (10), 206 (50), 207(5), 179 (5), 138 (9), 116 (100), 89 (48), 63 (18), 77 (5), 51(5).

1-(3-chlorobenzyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM): oven rate (10 °C·min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (19.44 min); White solid, mp 106-108°C; ¹H NMR (300 MHz, CDCl₃) δ: 5.54 (2H, s, N-CH₂), 7.16-7.43 (7H, m, 3H of Ar & 4H of Ar-Cl), 7.69 (1H, s, CH of triazole ring), 7.79-7.82 (2H, d, Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 53.4, 119.72, 125.68, 128.05, 128.01, 128.28, 128.85, 128.91, 130.33, 130.43, 134.92,
136.67, 148.31; MS: m/z (%): 269 (12), 240 (20), 206 (12), 207(5), 179 (5), 138 (9), 116 (100), 89 (35), 63 (18), 77 (5), 51(5).

1-(4-chlorobenzyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (19.14 min); White solid, mp 140-142°C; ¹H NMR (300 MHz, CDCl₃) δ: 5.52(2H, s, CH₂), 7.17 (2H, d, J =8.4 Hz, Ar), 7.24-7.44 (5H, m, Ar), 7.67 (1H, s, CH), 7.80 (2H, d, J =8.4 Hz, Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 53.4, 119.7, 125.6, 128.2, 128.8, 129.31, 129.35, 130.37, 133.24, 134.76, 148.32; MS: m/z (%): 269 (8), 240 (16), 206 (12), 179 (7), 138 (8), 125 (38) 116 (100), 89 (32), 63 (15), 77 (5), 51(5).

1-(2-Florobenzyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (17.46 min); White solid, mp 102-104°C; ¹H NMR (300 MHz, CDCl₃) δ: 5.62 (2H, s, N-CH₂), 7.09-7.42 (7H, m, Ar), 7.76-7.82 (2H, m, Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 47.67, 115.63, 115.90, 119.75, 121.88, 122.07, 124.83, 125.66, 128.71, 130.46, 130.81, 130.91, 148.14, 158.82, 162.11; MS: m/z (%): 253 (20), 224 (32), 198 (10), 130 (7), 124 (20), 116 (100), 109 (68), 102 (5), 89 (26), 83 (18), 77 (5), 63 (12), 51(5).

1-ethyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (12.14 min); White solid, mp 54-56°C; ¹H NMR (300 MHz, CDCl₃) δ: 1.57 (3H, triplet, J =7.33 Hz, CH₃), 4.45 (2H, quartet, J =7.33 Hz, N-CH₂), 7.76 (1H, s, N-CH), 7.26-7.38 (3H, m, Ar), 7.80-7.83 (2H, d, ortho to Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 15.50, 15.57, 45.23, 45.34, 119.02, 125.65, 128.06, 128.81, 129.78,
130.69, 147.74; MS: m/z (%): 173 (35), 144 (25), 130 (68), 117 (100) 103 (22), 90 (70), 89 (60), 77 (10), 63 (26), 51(15).

1-propyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (12.86 min); White solid, mp 62-64°C, ¹H NMR (300 MHz, CDCl₃) δ: 0.85-0.98 (3H, t, CH₃), 1.88-1.98 (2H, m, CH₂-CH₃), 4.30-4.35 (2H, t, N-CH₂-CH₂-CH₃), 7.26-7.43 (3H, m, Ar), 7.81-7.84 (2H, d, Ar), 7.75 (1H, s, CH); ¹³C NMR (75 MHz, CDCl₃) δ: 23.72, 29.68, 51.92, 119.52, 125.62, 128.01, 128.78, 130.70, 147.61; MS: m/z (%): 187 (25), 144 (13), 131 (35), 117 (100), 103 (26), 90 (35), 77 (15), 41(25).

1-butyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (14.24 min); White solid, mp 48-50°C; ¹H NMR (300 MHz, CDCl₃) δ: 0.96 (3H, t, CH₃-CH₂), 1.38 (2H, sextet, J =7.33 Hz, CH₂-CH₂), 1.92 (2H, quintet, J =7.33 Hz, CH₂-CH₂-CH₂), 4.39 (2H, t, J =7.33 Hz, N-CH₂), 7.26-7.44 (3H, m, Ar), 7.74 (1H, s, N-CH), 7.82 (2H, d, Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 13.57, 19.78, 32.37, 50.19, 119.48, 125.73, 128.12, 128.88, 130.79, 147.76; MS: m/z (%): 201 (24), 172 (18), 145 (14), 144 (12), 130 (17), 117 (100), 90 (24), 89 (22), 77 (12), 41 (25); Elemental analysis: found C 71.56, H 7.39, N 20.68, Calcd for C 71.64, H 7.46, N 20.89

1-pentyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (13.14 min); White solid, mp 68-70°C; ¹H NMR (300 MHz, CDCl₃) δ: 0.91 (3H, triplet, CH₃), 1.32-1.41 (4H, m, CH₂-CH₂), 1.95 (2H, quintet, J =7.33 Hz, CH₂), 4.39 (2H, triplet, J =7.33 Hz, N-CH₂), 7.32-7.45 (3H, m, ortho to Ar), 7.74 (1H, s, N-CH), 7.82-7.85 (2H, d, J =8.4 Hz, Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 13.83, 22.07, 28.55, 30.01, 50.37, 119.35, 125.62, 128.012, 128.77, 130.69, 147.65; MS: m/z (%): 215 (25),
186 (20), 172 (9), 158 (5), 145(1), 144(15), 130 (17), 117 (100), 104(25), 89 (24), 77 (14), 63 (10), 41 (50); Elemental analysis: found C 71.58, H 7.54, N 19.97, Calcd for C 71.55, H 7.90, N 19.53

1-allyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (13.20 min); White solid, mp 58-60°C; ¹H NMR (300 MHz, CDCl₃) δ: 4.96-4.99 (2H, d, J =6.2 Hz, N-CH₂), 5.27-5.36 (2H, dd, J =8 Hz & 16.86 Hz, allylic CH₂), 6.01-6.09 (1H, m, allylic CH), 7.27-7.43 (3H, m, Ar), 7.76 (1H, s, CH of triazole ring), 7.80-7.83 (2H, d, Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 51.36, 119.91, 120.08, 125.63, 128.08, 128.77, 130.54, 131.26, 147.88; MS: m/z (%): 185 (20), 156 (18), 116 (100), 89 (30), 63 (15), 77 (5), 41(16).

4-Phenyl-1,2,3-triazole-1-yl)-acetic acid ethyl ester:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (15.64 min); White solid, mp 102-104°C; IR (KBr): 768, 1045, 1078, 1223, 1466, 1758, 2950, 3004, 3079, 3125 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ: 1.33 (3H, triplet, J =7.69 Hz), 4.26 (2H, quartet, J =7.69 Hz), 5.20 (2H, s, N-CH₂), 7.40-7.41 (3H, m), 7.83-7.86 (2H, m, ortho to Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 14.05, 51.01, 62.39, 121.08, 125.74, 128.21, 128.80, 130.32, 148.12, 166.28; MS: m/z (%): 231 (30), 203 (14), 160 (18), 146 (20), 131 (40), 130 (50), 116 (100), 103 (62), 77 (42), 51 (18); Elemental analysis: found C 61.80, H 5.39, N 17.49, Calcd for C 61.63 H 5.62 N 17.58

1-isopropyl-4-phenyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (15.92 min); Light Yellow solid; ¹H NMR (300 MHz, CDCl₃) δ: 1.59 (6H, d, J =8.4 Hz, 2 CH₃), 4.85 (1H, m, J =8.4 Hz, N-CHMe₂), 7.26-7.43 (3H, m, Ar), 7.77 (1H, s, N-CH), 7.82 (2H, d, ortho to Ar); ¹³C NMR (......MHz, CDCl₃) δ: 23.08, 23.14, 53.02, 53.17, 117.18, 125.71, 128.06, 128.85, 130.90, 147.54; MS:
m/z (%): 187 (30), 159 (10), 144 (50), 132 (5), 117 (100), 103 (20), 102 (10), 89 (38), 77 (5), 63 (16), 51 (10), 43 (25), 41 (20).

1-benzyl-4-butyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10°C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (15.72 min); White solid, mp 56-58°C; ¹H NMR (300 MHz, CDCl₃) δ: 0.90 (3H, triplet, J =7.69 Hz, CH₃), 1.25-1.39 (2H, sextet, J =7.69 Hz, CH₂), 1.60 (2H, quintet, J =7.69 Hz, CH₂), 2.68 (2H, triplet, J =7.69 Hz, CH₂), 5.48 (2H, singlet, N-CH₂), 7.19-7.39 (6H, m, Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 13.78, 22.29, 25.36, 31.48, 53.92, 120.44, 120.55, 127.92, 128.54, 129.01, 134.99, 148.89; MS: m/z (%): 215 (2), 173 (7), 144 (5), 130 (4), 104 (6), 91 (100), 69 (4), 65 (12), 41 (10).

1-(2-chlorobenzyl)-4-butyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10°C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (17.12 min); White solid, mp 90-92°C; ¹H NMR (300 MHz, CDCl₃) δ: 5.52(2H, s, CH₂), 7.17 (2H, d, J =8.4 Hz, Ar), 7.24-7.44 (5H, m, Ar), 7.67 (1H, s, CH), 7.80 (2H, d, J =8.4 Hz, Ar); ¹³C NMR (75 MHz, CDCl₃) δ: 53.4, 119.7, 125.6, 128.2, 128.8, 129.31, 129.35, 130.37, 133.24, 134.76, 148.32; MS: m/z (%): 249 (2), 214 (2), 207 (7), 186 (4), 144 (4), 127 (32), 125 (100), 96 (3), 89 (21), 69 (6), 41 (15).

1-(3-chlorobenzyl)-4-butyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10°C · min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (16.62 min); Light yellow solid, mp 50-52°C; ¹H NMR (300 MHz, CDCl₃) δ: 0.98 (3H, triplet, J =7.69 Hz), 1.35 (2H, sextet, J =7.69 Hz), 1.63 (2H, quintet, J =7.69 Hz), 2.69 (2H, triplet, J =7.69 Hz), 5.46 (2H, singlet, N-CH₂), 7.20-7.33 (5H, m); ¹³C NMR (75 MHz, CDCl₃) δ: 13.74, 22.23, 25.29, 31.38, 53.12,
120.67, 120.57, 125.87, 128.68, 130.26, 134.78, 136.96, 149.03; MS: m/z (%): 249 (1), 220 (2), 207 (10), 178 (3), 164 (2), 138 (4), 127 (31), 125 (100), 89 (20), 69 (8), 41 (18).

1-(4-chlorobenzyl)-4-butyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C·min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (20.97 min); White solid, mp 54-56°C; ¹H NMR (300 MHz, CDCl₃) δ: 0.91 (3H, triplet, J = 7.69 Hz), 1.38 (2H, sextet, J = 7.69 Hz), 1.63 (2H, quintet, J = 7.69 Hz), 2.63 (2H, triplet, J = 7.69 Hz), 5.46 (2H, singlet, N-CH₂), 7.17-7.39 (5H, m); ¹³C NMR (75 MHz, CDCl₃) δ: 13.84, 22.37, 25.43, 31.53, 53.27, 120.54, 129.31, 133.58, 134.68, 149.20; MS: m/z (%): 249 (1), 207 (8), 178 (2), 164 (1), 138 (4), 127 (30), 125 (100), 89 (18), 69 (3), 41 (15).

1-(2-fluorobenzyl)-4-butyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C·min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (17.10 min); Brown oil; ¹H NMR (300 MHz, CDCl₃) δ: 0.91 (3H, triplet, J = 7.69 Hz), 1.37 (2H, sextet, J = 7.69 Hz), 1.62 (2H, quintet, J = 7.69 Hz), 2.69 (2H, triplet, J = 7.69 Hz), 5.45 (2H, singlet, N-CH₂), 7.10-7.39 (5H, m); ¹³C NMR (75 MHz, CDCl₃) δ: 13.76, 22.25, 25.29, 31.43, 47.40, 115.79, 120.74, 122.29, 124.72, 130.59, 148.85, 158.76, 162.05; MS: m/z (%): 233 (1), 204 (2), 191 (8), 176 (2), 162 (6), 122 (5), 109 (100), 96 (6), 83 (12), 69 (5), 41 (11).

1-pentyl-4-butyl-1H-1.2.3-triazole:
GC (capillary column, 30 m × 60 mm, ID-BP1 0.25 UM.): oven rate (10 °C·min⁻¹), initial column temp. (353 K), final column temp. (523 K), injection temperature (533 K), detection temperature (543 K), halt (2 min.), retention time (12.49 min); Yellow oil; ¹H NMR (300 MHz, CDCl₃) δ: 0.87-0.95 (6H, m, 2CH₃), 1.29-1.44 (6H, m, 3CH₂), 1.65 (2H, quintet, J = 7.33 Hz, CH₂), 1.86 (2H, quintet, J = 7.33 Hz, CH₂), 2.71 (2H, triplet, J = 7.33 Hz, CH₂), 4.30 (2H, triplet, J = 7.33 Hz, N-CH₂), 7.27 (1H, s, N-CH); ¹³C NMR (75 MHz, CDCl₃) δ: 13.91, 22.16, 22.37, 25.42, 28.67, 29.74, 30.11, 31.66, 50.21, 120.44, 148.45; MS: m/z (%): 195 (9), 151 (4), 152 (16), 124 (20), 110 (25), 96 (26), 82 (40), 68 (26), 54 (70), 41 (100).
Table 2, Entry 1:

![Chemical Structure](image)

[Chemical Analysis Data]

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Table 2, Entry 3:

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Table 2, Entry 4:
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Table 2, Entry 5:
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![Chemical Structure Image]

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Table 2, Entry 6:
Table 2, Entry 6:

![Chemical Structure](image)

**Table 2, Entry 6:**

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![Chemical Structure Image](image-url)
Table 2, Entry 7:
Table 2, Entry 8:

![Chemical Structure](image)
Table 2, Entry 9:

![Chemical Structure Image]
Table 2, Entry 9:
Table 2, Entry 11:

![Chemical Structure](image)
Table 2, Entry 11:
Table 2, Entry 12:
Table 2, Entry 12:

![Chemical Structure](image)
Table 2, Entry 14:

![Chemical Structure Image]

**Table 2, Entry 14:**

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<th>MW</th>
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</tbody>
</table>

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Table 2, Entry 14:
Table 2, Entry 15:

![Diagram of molecular structure]

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Table 2, Entry 15:
Table 2, Entry 16:

![Chemical Structure Image]
Table 2, Entry 16:
Table 2, Entry 19:

![Chemical Structure](image)
Table 2, Entry 19:

![Chemical Structure Image]

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Table 2, Entry 20:
Table 2, Entry 20:

\[ \text{N} \equiv \text{N} \]

\begin{align*}
\text{N} & \equiv \text{N} \\
\text{Cl} & \\
\end{align*}
Table 2, Entry 21:
Table 2, Entry 21:
Table 2, Entry 22:
Table 2, Entry 22:
5. GC-MS spectra: