

ELECTRONIC SUPPLEMENTARY INFORMATION

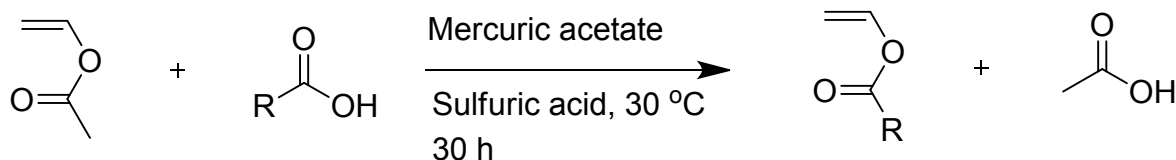
Structure-activity investigations on amphiphilic cationic copolymers of vinyl N,N-dimethylethylglycinate with vinyl alkananoate esters as highly effective antibacterial agents

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S1. Synthesis of Monomers.¹



R = a) Propyl
b) Butyl
c) pentyl
d) hexyl

Viny

l butyrate, vinyl valerate, vinyl hexanoate, and vinyl heptanoate were synthesized by transvinylolation reaction between vinyl acetate and corresponding acid, using mercuric acetate as catalyst. Heptanoic acid (20 mL, 141 mmol) was added into a 250 mL single round bottom flask, already charged with 0.4g mercuric acetate (1.26 mmol) and vinyl acetate (78 mL, 846 mmol). Sulfuric acid (0.07 mL, 1.32 mmol) was then added dropwise under stirring. The reaction was stirred at 30 °C for 30 hours. Excess sulfuric acid was neutralized by adding 0.2 g sodium acetate, followed by filtration. Vinyl acetate was evaporated using rotavapor, and resultant liquid was purified using silica gel chromatography using dichloromethane as eluent. Solvent was evaporated using rotavapor and pure monomer was obtained as a clear liquid (12.2 g, 55.4% yield). All other monomers were similarly synthesized. **Vinyl heptanoate** ¹H NMR (600 MHz, CDCl₃, δ): 7.27 (q, 1H), 4.86 (d, 1H), 4.55 (d, 1H), 2.37 (t, 2H), 1.64 (m, 2H), 1.24-1.36 (m, 6H), 0.88 (t, *J* = 7 Hz, 3H). **Vinyl Butyrate** ¹H NMR (600 MHz, CDCl₃, δ): 7.28 (q, 1H), 4.87 (dd, 1H), 4.56 (dd, 1H), 2.39 (t, 2H), 1.65 (m, 2H), 1.34-1.41 (m, 2H), 0.93 (t, 3H). **Vinyl Valerate** ¹H NMR (600 MHz,

CDCl₃, δ): 7.28 (q, 1H), 4.87 (dd, 1H), 4.56 (dd, 1H), 2.39 (t, 2H), 1.65 (m, 2H), 1.34 -1.41 (m, 2H), 0.93 (t, 3H). **Vinyl hexanoate** ¹H NMR (600 MHz, CDCl₃, δ): 7.27 (q, 1H), 4.85 (d, 1H), 4.54 (d, 1H), 2.36 (t, 2H), 1.65 (m, 2H), 1.27-1.37 (m, 4H), 0.89 (t, 3H).

S2. ¹H NMR spectra of 2.3k g/mol series copolymers before quaternization.

CP-methyl_{2.3k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 1.67 – 2.15 (bm, 16H), δ 2.50 – 2.94 (bm, 4H), δ 3.61 – 3.79 (s, 3H), δ 3.94 – 4.13 (bs, 6H), δ 4.15 – 4.40 (bs, 2H), δ 4.61 – 5.32 (bm, 4H).

CP-ethyl_{2.3k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.96 – 1.19 (bm, 9H), δ 1.57 – 2.09 (bm, 14H), δ 2.15 – 2.40 (bm, 6H), δ 2.51 – 2.93 (m, 4H), δ 3.60 – 3.76 (s, 3H), δ 3.92 – 4.12 (bs, 8H), δ 4.16 – 4.42 (m, 2H), δ 4.71 – 5.24 (bm, 5H).

CP-propyl_{2.3k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.78 – 1.10 (bm, 11H), δ 1.50 – 2.09 (bm, 29H), δ 2.12 – 2.42 (bm, 8H), δ 2.51 – 2.96 (m, 4H), δ 3.60 – 3.78 (s, 3H), δ 3.94 – 4.17 (bs, 12H), δ 4.19 – 4.40 (m, 2H), δ 4.69 – 5.36 (bm, 8H).

CP-butyl_{2.3k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.83 – 0.98 (bm, 8H), δ 1.25 – 1.42 (bm, 6H), δ 1.49 – 2.12 (bm, 22H), δ 2.14 – 2.41 (bm, 6H), δ 2.55 – 2.86 (m, 4H), δ 3.98 – 4.13 (bs, 10H), δ 4.17 – 4.39 (m, 2H), δ 4.70 -5.28 (bm, 6H).

CP-pentyl_{2.3k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.79 – 1.02 (bm, 16H), δ 1.16 – 1.43 (bm, 22H), δ 1.48 – 2.13 (bm, 42H), δ 2.15 – 2.42 (bm, 12H), δ 2.48 – 2.93 (m, 4H), δ 3.61 – 3.74 (s, 3H), δ 3.95 – 4.12 (bs, 16H), δ 4.15 – 4.41 (m, 2H), δ 4.64 – 5.27 (bm, 12 H).

CP-hexyl_{2.3k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.79 – 0.94 (bm, 13H), δ 1.19 – 1.38 (bm, 26H), δ 1.43 – 2.10 (bm, 33H), δ 2.13 – 2.39 (bm, 9H), δ 2.51 – 2.94 (m, 4H), δ 3.62 – 3.74 (s, 3H), δ 3.95 – 4.12 (bs, 15H), δ 4.16 – 4.39 (m, 2H), δ 4.64 – 5.23 (bm, 9H).

S3. ¹H NMR spectra of 4k g/mol series copolymers before quaternization.

CP-methyl_{4k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 1.43 – 2.21 (bm, 140 H), δ 2.5 - 2.90 (m, 4H), δ 3.63 – 3.74 (s, 3H), δ 3.93 – 4.17 (bs, 50H), δ 4.68 – 5.31 (bm, 37H).

CP-ethyl_{4k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.98 – 1.20 (bm, 57H), δ 1.56 – 2.10 (bm, 91H), δ 2.15 – 2.42 (bm, 37H), δ 2.53 – 2.95 (m, 4H), δ 3.62 – 3.75 (s, 3H), δ 3.97 – 4.15 (bs, 49H), δ 4.69 – 5.24 (bm, 40H).

CP-propyl_{4k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.85 – 1.06 (bm, 48H), δ 1.46 – 2.10 (bm, 128H), δ 2.13 – 2.41 (bm, 33H), δ 2.53 – 2.95 (m, 4H), δ 3.62 – 3.74 (s, 3H), δ 3.97 – 4.15 (bs, 40H), δ 4.70 – 5.30 (bm, 33H).

CP-butyl_{4k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.66 – 0.93 (bm, 57H), δ 1.12 – 1.32 (bm, 40H), δ 1.37 – 1.57 (bm, 42H), δ 1.58 – 2.05 (bm, 104H), δ 2.06 – 2.33 (bm, 41H), δ 2.39 – 2.87 (m, 4H), δ 3.54 – 3.65 (s, 3H), δ 3.84 – 4.08 (bs, 59H), δ 4.58 – 5.12 (bm, 47H).

CP-pentyl_{4k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.79 – 0.98 (bm, 51H), δ 1.15 – 1.39 (bm, 70H), δ 1.47 – 2.08 (bm, 125H), δ 2.14 – 2.40 (bm, 35H), δ 2.53 – 2.95 (m, 4H), δ 3.62 – 3.74 (s, 3H), δ 3.93 – 4.15 (bs, 45H), δ 4.68 – 5.23 (bm, 36H).

CP-hexyl_{4k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.78 – 0.96 (bm, 53H), δ 1.15 – 1.40 (bm, 107H), δ 1.47 – 2.08 (bm, 129H), δ 2.15 – 2.37 (bm, 35H), δ 2.51 – 2.99 (m, 4H), δ 3.59 – 3.74 (s, 3H), δ 3.91 – 4.14 (bs, 47H), δ 4.67 – 5.25 (bm, 37H).

S4. ¹H NMR spectra of 7k g/mol series copolymers before quaternization.

CP-methyl_{7k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 1.42 – 2.30 (bm, 3.04), δ 3.83 – 4.08 (bs, 1.00), δ 4.56 – 5.21 (bm, 0.84).

CP-ethyl_{7k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.79 – 1.07 (bm, 1.19), δ 1.39 – 1.94 (bm, 2.11), δ 1.99 – 2.42 (bm, 0.81), δ 3.74 – 4.00 (bs, 1.00), δ 4.46 – 5.14 (bm, 0.87).

CP-propyl_{7k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.61 – 0.92 (bm, 1.12), δ 1.29 – 1.94 (bm, 2.75), δ 1.97 – 2.28 (bm, 0.88), δ 3.81 – 4.03 (bs, 1.00), δ 4.57 – 5.14 (bm, 0.90).

CP-butyl_{7k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.79 – 0.99 (bm, 1.22), δ 1.23 – 1.37 (bm, 0.84), δ 1.46 – 1.63 (bm, 0.85), δ 1.65 – 2.09 (bm, 2.06), δ 2.12 – 2.39 (bm, 0.89), δ 3.95 – 4.16 (bs, 1.00), δ 4.65 – 5.30 (bm, 1.04).

CP-pentyl_{7k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.66 – 0.92 (bm, 1.30), δ 1.05 – 1.32 (bm, 1.74), δ 1.37 – 1.54 (bm, 0.90), δ 1.56 – 2.00 (bm, 1.88), δ 2.05 – 2.31 (bm, 0.91), δ 3.84 – 4.10 (bs, 1.00), δ 4.61 – 5.13 (bm, 0.92).

CP-hexyl_{7k} (Step 1) ¹H NMR (600 MHz, CDCl₃): δ 0.74 – 0.96 (bm, 1.65), δ 1.12 – 1.41 (bm, 3.02), δ 1.45 – 2.08 (bm, 3.56), δ 2.10 – 2.44 (bm, 0.93), δ 3.92 – 4.20 (bs, 1.00), δ 4.59 – 5.12 (bm, 0.91).

S5. ¹H NMR spectra of 2.3k g/mol series copolymers after quaternization.

CP-methyl_{2.3k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 1.14 – 1.34 (bm, 11H), δ 1.56 – 2.18 (bm, 17H), δ 2.53 – 2.81 (m, 4H), δ 3.13 – 3.39 (bs, 20H), δ 3.53 – 3.84 (bm, 11H), δ 4.22 – 5.40 (bm, 13H).

CP-ethyl_{2.3k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.84 – 1.03 (bm, 10H), δ 1.16 – 1.38 (bm, 15H), δ 1.55 – 2.06 (bm, 16H), δ 2.10 – 2.38 (bm, 8H), δ 2.55 – 2.81 (m, 4H), δ 3.16 – 3.42 (bs, 28H), δ 3.54 – 3.87 (bm, 12H), δ 4.20 – 5.33 (bm, 19H).

CP-propyl_{2.3k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.73 – 0.89 (bm, 13H), δ 1.15 – 1.31 (bm, 19H), δ 1.34 – 1.56 (bm, 10H), δ 1.56 – 2.34 (bm, 33H), δ 2.51 – 2.83 (bm, 4H), δ 3.13 – 3.41 (bs, 38H), δ 3.55 – 3.83 (bm, 15H), δ 4.18 – 5.50 (bm, 27H).

CP-butyl_{2.3k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.74 – 0.87 (bm, 8H), δ 1.17 – 1.31 (bm, 17H), δ 1.34 – 2.02 (bm, 19H), δ 2.03 – 2.34 (bm, 6H), δ 2.54 – 2.78 (m, 4H), δ 3.11 – 3.39 (bs, 23H), δ 3.64 – 3.84 (bm, 10H), δ 4.08 – 5.30 (bm, 15H).

CP-pentyl_{2.3k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.73 – 0.92 (bm, 13H), δ 1.22 – 1.35 (bm, 35H), δ 1.40 – 2.42 (bm, 40H), δ 2.57 – 2.86 (bm, 4H), δ 3.13 – 3.32 (bs, 37H), δ 3.47 – 3.71 (bm, 17H), δ 4.12 – 5.21 (bm, 21H).

CP-hexyl_{2.3k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.73 – 0.88 (bm, 24H), δ 1.06 – 1.31 (bm, 94H), δ 1.32 – 1.53 (bm, 21H), δ 1.55 – 2.32 (bm, 64H), δ 2.54 – 2.77 (m, 4H), δ 3.13 – 3.37 (bm, 62H), δ 3.61 – 3.82 (bm, 23H), δ 4.25 – 5.12 (bm, 50H).

S6. ¹H NMR spectra of 4k g/mol series copolymers before quaternization.

CP-methyl_{4k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 1.13 – 1.34 (bm, 55H), δ 1.42 – 2.30 (bm, 140H), δ 3.10 – 3.36 (bs, 107H), δ 3.53 – 3.84 (bm, 46H), δ 4.27 – 5.32 (bm, 77H).

CP-ethyl_{4k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.81 – 1.05 (bm, 57H), δ 1.14 – 1.35 (bm, 58H), δ 1.57 – 2.04 (bm, 72H), δ 2.10 – 2.35 (bm, 35H), δ 3.10 – 3.35 (bs, 113H), δ 3.51 – 3.76 (bm, 33H), δ 4.39 – 5.17 (bm, 62H).

CP-propyl_{4k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.75 – 0.90 (bm, 57H), δ 1.15 – 1.30 (bm, 58H), δ 1.35 – 1.55 (bm, 42H), δ 1.59 – 2.02 (bm, 75H), δ 2.04 – 2.31 (bm, 40H), δ 3.12 – 3.34 (bs, 113H), δ 3.53 – 3.73 (bm, 36H), δ 4.40 – 5.13 (bm, 66H).

CP-butyl_{4k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.71 – 0.90 (bm, 59H), δ 1.13 – 1.31 (bm, 107H), δ 1.33 – 1.50 (bm, 44H), δ 1.57 – 2.03 (bm, 87H), δ 2.08 – 2.36 (bm, 40H), δ 3.12 – 3.35 (bs, 135H), δ 4.35 – 5.31 (bm, 86H).

CP-pentyl_{4k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.73 – 0.91 (bm, 62H), δ 1.09 – 1.32 (bm, 139H), δ 1.35 – 1.53 (bm, 45H), δ 1.57 – 2.03 (bm, 74H), δ 2.05 – 2.35 (bm, 44H), δ 3.14 – 3.37 (bs, 106H), δ 3.55 – 3.79 (bm, 40H), 4.28 – 5.36 (bm, 76H)

CP-hexyl_{4k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.74 – 0.89 (bm, 59H), δ 1.08 – 1.32 (bm, 170H), δ 1.34 – 1.54 (bm, 43H), δ 1.56 – 2.02 (bm, 68H), δ 2.06 – 2.33 (bm, 38H), δ 3.11 – 3.32 (bs, 104H), δ 3.52 – 3.77 (bm, 41H), δ 4.38 – 5.37 (bm, 81H).

S7 ¹H NMR spectra of 7k g/mol series copolymers before quaternization.

CP-methyl_{7k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 1.17 – 1.39 (bm, 3.3), δ 1.65 – 2.19 (bm, 6H), δ 3.18 – 3.41 (bs, 6H), δ 3.61 – 3.83 (bs, 2H), δ 4.50 – 5.20 (bm, 4H).

CP-ethyl_{7k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.89 – 1.12 (bm, 3H), δ 1.18 – 1.40 (bm, 3H), δ 1.63 – 2.42 (bm, 5H), δ 3.17 – 3.43 (bs, 6H), δ 3.60 – 3.83 (bs, 2H), δ 4.52 – 5.23 (bm, 4H).

CP-propyl_{7k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.69 – 0.90 (bm, 3H), δ 1.08 – 1.32 (bm, 3H), δ 1.35 – 1.55 (bm, 2H), δ 1.61 – 2.37 (bm, 6H), δ 3.12 – 3.36 (bs, 6H), δ 3.53 – 3.78 (bs, 2H), δ 4.30 – 5.20 (bm, 4H).

CP-butyl_{7k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.74 – 0.92 (bm, 3H), δ 1.13 – 1.31 (bm, 5H), δ 1.33 – 1.52 (bm, 2H), δ 1.55 – 2.36 (bm, 6H), δ 3.13 – 3.36 (bs, 6H), δ 3.52 – 3.80 (bs, 2H), δ 4.42 – 5.21 (bm, 4H).

CP-pentyl_{7k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.76 – 0.89 (bm, 3H), δ 1.11 – 1.33 (bm, 8H), δ 1.35 – 1.55 (bm, 3H), δ 1.60 – 2.36 (bm, 8H), δ 3.11 – 3.35 (bs, 6H), δ 3.52 – 3.78 (bs, 2H), δ 4.34 – 5.31 (bm, 4H).

CP-hexyl_{7k} (quaternized) ¹H NMR (600 MHz, D₂O): δ 0.78 – 0.92 (bm, 3H), 1.14 – 1.32 (bm, 10H), 1.35 – 1.53 (bm, 3H), 1.65 – 2.36 (bm, 7H), 3.14 – 3.36 (bs, 6H), 3.56 – 3.77 (bs, 2H), 4.49 – 5.18 (bm, 4H).

S7 Calculation of degree of polymerization and actual mole percent of comonomers in the copolymer.

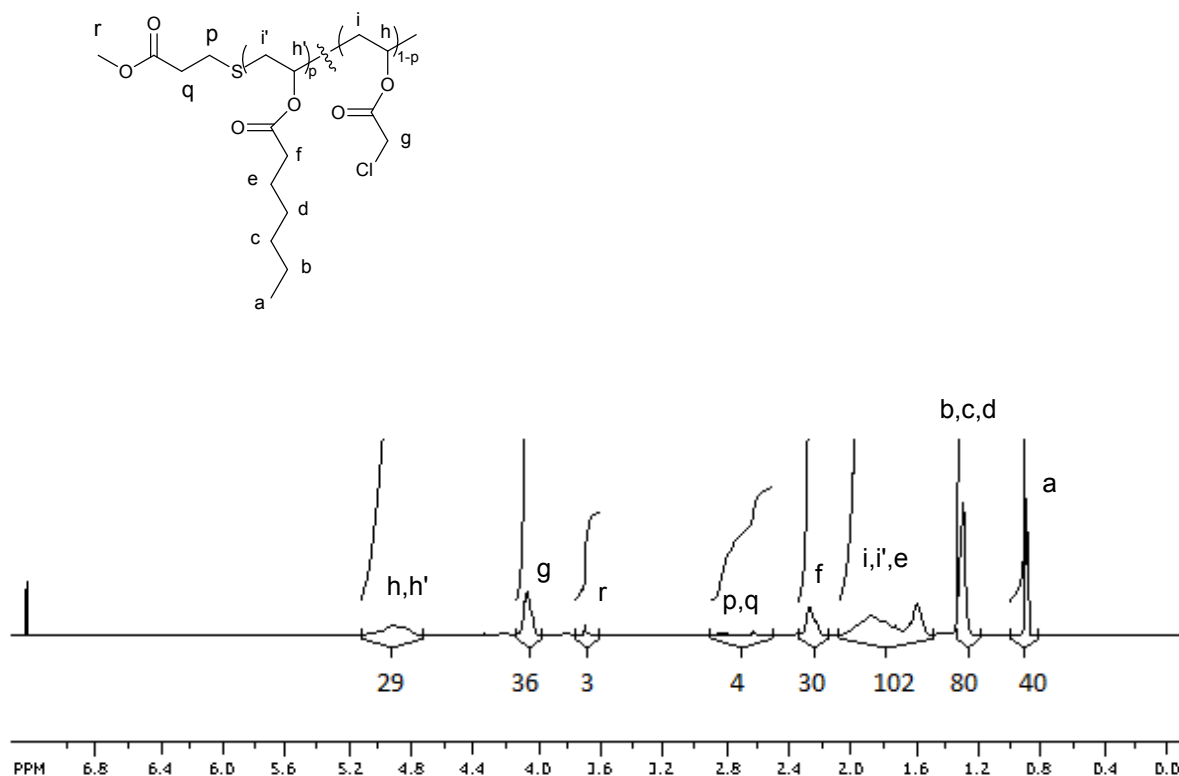


Figure S1. ¹H NMR spectrum of CP-hexyl_{5k}

In Figure S1, a single peak at δ 3.7 belongs to the methyl protons (r) at the chain end. A broad single peak at δ 3.97-4.14 (g) belongs to methylene protons in vinyl chloroacetate monomer repeat unit. Methylene protons in vinyl heptanoate monomer repeat unit (f) give a chemical shift at δ 2.15 – 2.34. Approximate degree of polymerization is calculated as below assuming chain transfer as mode of termination:

$$\text{Degree of Polymerization} = [(36/2) + (30/2)] \div (3/3) = 33$$

$$\text{Mole \% of vinyl chloroacetate repeat units: } 36 \div (36 + 30) = 55\%$$

$$\text{Mole \% of vinyl heptanoate repeat units: } 30 \div (36 + 30) = 45\%$$

Table S1. Molecular weight characterization of copolymers through gel permeation chromatography.

Copolymer	Mw (Da)	Polydispersity index
CP-methyl _{2.3k}	1878	1.32
CP-ethyl _{2.3k}	2076	1.31
CP-propyl _{2.3k}	2363	1.32
CP-butyl _{2.3k}	2216	1.29
CP-pentyl _{2.3k}	2722	1.33
CP-hexyl _{2.3k}	2780	1.33
CP-methyl _{4k}	3487	1.50
CP-ethyl _{4k}	3469	1.51
CP-propyl _{4k}	3188	1.41
CP-butyl _{4k}	4230	1.43
CP-pentyl _{4k}	4163	1.49
CP-hexyl _{4k}	5269	1.56
CP-methyl _{7k}	6382	1.53
CP-ethyl _{7k}	6315	1.65
CP-propyl _{7k}	7097	1.68
CP-butyl _{7k}	5134	1.31
CP-pentyl _{7k}	10141	1.63
CP-hexyl _{7k}	10498	1.58

References

1. (a) H. Hopff and M. A. Osman, *Tetrahedron*, 1968, 24(5), 2205; (b) H. Hopff and M. A. Osman, *Tetrahedron*, 1968, 24(10), 3887; (c) D. Swern and E. F. Jordan Jr., *Org. Synth.*, 1963, 4, 977; (d) W. O. Herrman and W. Haehnel, *U. S. Patent*, 1941, 2245131; (e) W. J. Toussaint and L. G. MacDowell, *U.S. Patent*, 1942, 2299862.