ELSEVIER

Dyes and Pigments 44 (2000) 81–86

DYES and PIGMENTS

Synthesis and fluorescence spectroscopy of bis(*ortho*- and *para*-carbonyl)phenyl glycols

Hülya Tuncer, Çakıl Erk*

Chemistry Department, Organic Chemistry Laboratories, Technical University of Istanbul, Maslak, 80626, Istanbul, Turkey

Received 24 November 1998; accepted 16 July 1999

Abstract

Bis-(2′- or 4′-carbonyl)phenyl glycols (podands) were synthesized by reacting *ortho*- and *para*-vanillin and 2′- and 4′-hydroxy acetophenone with mono or diethylene glycol dihalides. The products were characterised using IR, ^{1}H-NMR, ^{13}C-NMR spectroscopy and mass spectrometry. Aromatic carbonyl derivatives of glycols were investigated to determine the role of Na^+ ions, using steady state fluorescence spectroscopy. © 1999 Elsevier Science Ltd. All rights reserved.

1. Introduction

The ability of polyethylene glycols to bind cations has long been recognised, and many of these compounds have been synthesized and investigated as substrates for cation recognition [1]. They are also known to transport cations across membranes like the naturally occurring compounds they mimic [1,2]. However, their fast ligand–cation exchange rate, while causing limited binding power, has been used in the design of ion detectors that work via potentiometry or spectroscopy [1–5]. These types of studies have also shown that cation–ligand interactions are governed by podand end groups and the ability of the polyglycol chains to adopt the conformation required to bind cations [4,5].

Polyethylene glycol group binding of cation by chelation has been known since the use of pure polyethylene glycol chains to solvate salts. It is also known that end groups may play a specific role in the chelation process depending on their polarity [1–5]. The additional binding sites comprising polar end groups may play important roles [6,7] in enhancing binding efficiency, mimicing the role of calixaranes [6–12].

Open chain ionophores have proved to be quite interesting compounds due to their versatility as microbiological agents and in ion binding. Their extraordinary capacity for ion binding is especially interesting in view of their acyclic and bulky structures. The acyclic backbone can undergo conformational changes forming a pseudocyclic cavity upon metal inclusion. This process is governed by the energy barriers to conformations affording maximum ion binding enthalpy.

Several types of polyethylene glycols have been synthesised and shown to be synthetic podands with oxygen donors. The well-known *glymes* have shown interesting behaviour, forming crystalline complexes that bind alkali metals as well as heavy

---

* Corresponding author.

PII: S0143-7208(99)00075-3

metal cations such as Hg^{2+}, Fe^{2+}, Mn^{2+}, Co^{2+}, Cu^{2+} and Ni^{2+}. The bis-end groups of such chains are believed to influence molecular conformations and provide additional binding sites for the metals.

We recently synthesised some bis-coumarin ended glycols and investigated their ion–ligand interactions, using fluorescence spectroscopy as a method for measuring Pd^{2+} [6–9]. Structures containing oxyethylene units have been utilised as potentiometric ion sensors in PVC matrix membranes owing to their binding at a fast metal-ligand exchange rate [13–18]. Such ionophores would exhibit a free energy of activation around 45–65 kJ/mol for the cation–ligand exchange reaction.

The present work deals with the synthesis and characterization of bis (2′-or 4′-substituted) phenyl-ended mono and diethylene glycols (podands) as neutral ligands for binding cations. We also attempted to make bis-hydroxy aromatic glycol derivatives; however, the required hydroxylation step was unsuccessful [10,11].

2. Results and discussion

We investigated primarily the preparation of short chain glycols with semi-polar end groups arising from an oxyethylene chain skeleton. This was our focus because long oxyethylene chains are not likely to form structures having the conformations needed to chelate cations [6,7,9]. This conclusion is based in part on our experience with macrocycles, including extensive studies involving glyme type ionophores.

In the present work the podands were prepared in good yields from *ortho* and *para* vanillins and 2- and 4-hydroxyacetophenones by alkylating with 1,2-dibromoethane or β,β'-dichlorodiethyl ether in the presence of Na_2CO_3/DMF or DMSO (Scheme 1).

The substitution of hydroxyl groups for carbonyl groups on podands was attempted in acidic and basic solutions in the presence of H_2O_2, following Bayer–Williger procedures, but the results were generally unsatisfactory. Though we did obtain compound **4a** in a moderate yield, other podands employed this work failed to give the desired hydroxylated products (see Scheme 2) [10,11,19].

Results of fluorescence studies conducted with bis-aromatic carbonyl ended glymes were quite interesting, due to the effects of $NaClO_4$ in CH_3CN (see Table 1 and Fig 1). Sodium ions enhanced the intensity of fluorescence emission by complexing with the carbonyl functional groups. Insertion of glyme chains into aromatic carbonyl compounds altered the fluorescence life times, in general. It is possible that such alterations originated from conformational changes in the chromophore as well as from cation–chromophore interactions.

3. Experimental

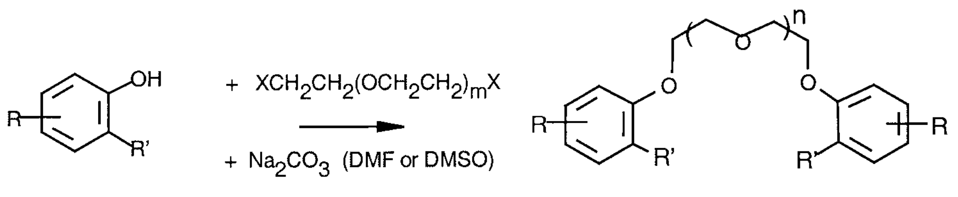
The chemicals used were obtained from Fluka unless otherwise cited and were used without further purification. Melting points (mp) were not corrected. NMR data were obtained with a 400 mHz Bruker spectrometer, Model Avance 400 DPX. EI mass spectra were obtained with a Fisons model MD-800 spectrometer using a direct inlet probe. IR spectra were obtained on KBr pellets using a Jeol FT-IR spectrometer, model 5300. The synthetic procedures, reaction yields and analytical data for compounds **3a–3h** and **4a** are given below.

Steady-state fluorescence emission and excitation measurements of the free and $NaClO_4$ containing compounds were carried out using an LS-50 Perkin–Elmer luminescence spectrophotometer, in dry CH_3CN with 10 nm spectral width. Excess $NaClO_4$ was used to determine the effect of cations in cation–salt combinations.

3.1. 1,2-bis(2-Methoxy-6-formylphenoxy)ethane (**3a**)

A mixture of 1,2-dibromoethane (9.4 g, 0.05 mol), *ortho*-vanillin (15.2 g, 0.10 mol) and Na_2CO_3 (10.6 g, 0.10 mol) and DMF (90 ml) was stirred for 90 h at 90–95°C. The cooled reaction mixture was diluted with water (60 ml) and HCl (2 N, 20 ml) was added. The crude product was filtered, dissolved in $CHCl_3$, dried with Al_2O_3 (5 g) and the solvent was removed. Recrystallization from acetone gave 13.2 g (80%)

3a, mp 119°C; IR $\nu = 2953, 1702, 1497, 1193, 1089$ cm^{-1}; ^{1}H-NMR 400 MHz ($CHCl_3$/TMS) $\delta = 3.89$ (6H, MeO), 4.52 (4H, s, OC_2H_4O), 7.16 (4H, m, Ar), 7.46 (2H, m, Ar), 10.56 (2H, s, CHO); ^{13}C-NMR 100 MHz ($CDCl_3$/TMS) $\delta = 73.9$, 131.2, 119.1, 120.4, 125.4, 154.2, 153.0, 192.0, 56.7; EI MS MW 330.34 for $C_{18}H_{16}O_6$; *m/z* 330.6, 179.4, 151.3, 108.1, 77.1.

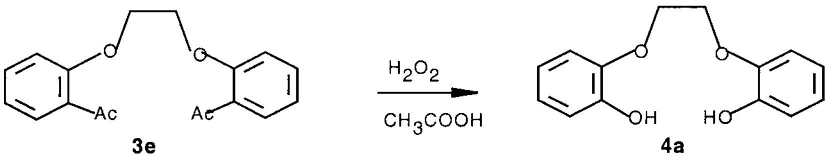


	x	m
1a	Br	0
1b	Cl	1

	R'	R
2a	6-CHO	2-OCH_3
2b	4-CHO	2-OCH_3
2c	2-$COCH_3$	H
2d	4-$COCH_3$	H

	n	R	R'
3a	0	6-CHO	2-OCH_3
3b	0	4-CHO	2-OCH_3
3c	1	6-CHO	2-OCH_3
3d	1	4-CHO	2-OCH_3
3e	0	2-$COCH_3$	H
3f	0	4-$COCH_3$	H
3g	1	2-$COCH_3$	H
3h	1	4-$COCH_3$	H

Scheme 1. Synthesis of type **3** compounds.



Scheme 2. Oxidation of **3e** to target compound **4a**.

Table 1
Fluorescence data for free and Na$^+$ containing aromatic carbonyl compounds and bis-aromatic carbonyl ended glymes in CH_3CN at room temperature

Compound no.	Excite$_{max}$ (nm)	Emiss$_{max}$ (nm)	Podand conc. (mol/l)	Podand spec. intensity	Podand and salt combination		Combination spec. emiss intensity
					Podand conc.	Salt conc.	
2a	333	474	5.0×10^{-5}	8.3	3.3×10^{-5}	3.3×10^{-3}	79.7
2b	333	474	5.0×10^{-5}	8.3	3.3×10^{-5}	3.3×10^{-3}	85.5
2c	333	474	5.0×10^{-5}	6.9	3.3×10^{-5}	3.3×10^{-3}	78.4
2d	333	474	5.0×10^{-5}	8.5	3.3×10^{-5}	3.3×10^{-3}	87.2
3a	336	474	5.0×10^{-5}	9.3	3.3×10^{-5}	3.3×10^{-3}	63.3
3b	339	475	5.0×10^{-5}	14.9	3.3×10^{-5}	3.3×10^{-3}	83.3
3c	341	475	5.0×10^{-5}	13.8	3.3×10^{-5}	3.3×10^{-3}	75.0
3d	341	476	5.0×10^{-5}	73.4	3.3×10^{-5}	3.3×10^{-3}	111.7
3e	338	476	5.0×10^{-5}	82.6	3.3×10^{-5}	3.3×10^{-3}	117.2
3f	336	474	5.0×10^{-5}	21.9	3.3×10^{-5}	3.3×10^{-3}	89.9
3g	336	473	5.0×10^{-5}	8.1	3.3×10^{-5}	3.3×10^{-3}	82.6
3h	335	474	5.0×10^{-5}	28.7	3.3×10^{-5}	3.3×10^{-3}	93.6

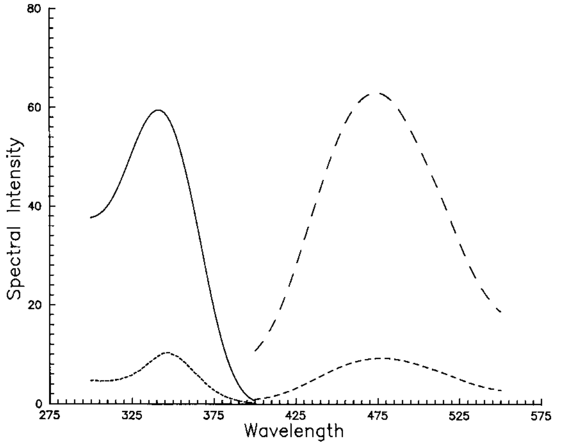


Fig. 1. Excitation fluorescence spectra of free compound **1a** (····) and its complex (—) with Na^+ (upper curves). Emission fluorescence spectra of free compound **1a** (- - - -) and its complex (– –) with Na^+ (lower curves).

3.2. *1,2-bis(2-Methoxy-4-formylphenoxy)ethane* (**3b**)

1,2-Dibromoethane (9.40 g, 0.05 mol), *para*-vanillin (15.2 g, 0.1 mol) and Na_2CO_3 (10.60 g, 0.10 mol) and DMF (60 ml) were stirred for 90 h at 90°C. The cooled reaction mixture was diluted with water (60 ml) and HCl (2 N, 20 ml) was added. The crude product was isolated as described above for **3a** and recrystallized from THF to give **3b**, 14.45 g (88%), mp 180°C; IR $\nu = 2944$, 1683, 1588, 1266, 1022 cm^{-1}; ^{1}H-NMR 400 MHz, (DMSO-d_6/TMS) $\delta = 3.30$ (6H, s, CH_3O), 4.49 (4H, s, OC_2H_4O), 7.26 (2H, m, Ar), 7.55 (4H, m, Ar), 9.85 (2H, s, CHO); ^{13}C-NMR 100 MHz (DMSO-d_6/TMS) $\delta = 67.7$, 110.04, 131.7, 127.6, 151.3, 155.2, 192.4, 56.7; MW 330.34 for $C_{18}H_{16}O_6$; EI MS *m*/*z* 330.6, 179.4, 151.3, 108.1, 77.1.

3.3. *1,5-bis(2-Methoxy-6-formylphenoxy)-3-oxapentane* (**3c**)

β, β'-Dichlorodiethylether (3.6 g, 0.025 mol), *ortho*-vanillin (7.6 g, 0.05 mol) and K_2CO_3 (6.91 g, 0.05 mol) and DMF (50 ml) were stirred for 100 h at 95°C. The cooled reaction mixture was diluted with water (60 ml) and HCl (2 N, 20 ml) was added. Isolation of the crude product as described above for **3b** and recrystallization from hot EtOH gave **3c**, 5.43 g (58%), mp 75°C; IR $\nu = 2953$, 2902, 1702, 1472, 1268, 1089 cm^{-1}; ^{1}H-NMR 400 MHz ($CDCl_3$/TMS) $\delta = 3.79$ (4H, *t*, J = 4.2, CH_2O), 3.88 (6, s, CH_3O), 4.31 (4H, t, *J* = 4.2, CH_2O), 7.12 (4H, m, Ar), 7.31 (2H, m, Ar), 10.51 (2H, s, CHO); ^{13}C-NMR 100 MHz ($CDCl_3$/TMS) $\delta = 71.1$, 73.9, 119.1, 120.1, 125.2, 131.3, 152.7, 154.2, 192.3, 56.8; MW 374.39 for $C_{20}H_{22}O_7$; EI MS *m*/*z* 374.6, 223.4, 179.4, 151.3, 109.1, 108.2, 77.2.

3.4. *1,5-bis(2-Methoxy-4-formylphenoxy)-3-oxapentane* (**3d**)

β, β'-Dichlorodiethylether (3.6 g, 0.025 mol), *para*-vanillin (7.6 g, 0.05 mol) and K_2CO_3 (6.91 g, 0.050 mol), DMF (40 ml) were stirred for 90 h at 95°C. The cooled reaction mixture was diluted with water (60 ml) and HCl (2 N, 20 ml) was added. The crude product was isolated as described above for **3c** and recrystallized from MeOH to give **3d**, 8.13 g (81%), mp 126–129°C; IR $\nu = 2927$, 1702, 1446, 1268, 1089 cm^{-1}; ^{1}H-NMR 400 MHz ($CDCl_3$/TMS) $\delta = 3.92$ (6H, s, CH_3O), 4.03 (4H, *t*, *J* = 4.2, CH_2O), 4.30 (4H, *t*, *J* = 4.2, CH_2O), 7.02 (2H, m, Ar), 7.43 (4H, m, Ar), 9.86 (2H, s, CHO); ^{13}C-NMR 100 MHz ($CDCl_3$/TMS) $\delta = 70.6$, 69.4, 113.1, 110.0, 131.7, 127.6, 155.2, 151.3, 192.4, 56.7; MW 374.39 for $C_{20}H_{22}O_7$, EI MS *m*/*z* 374.6, 223.4, 179.4, 151.3, 108.2, 77.2.

3.5. *1,2-bis(2-Acetylphenoxy)ethane* (**3e**)

1,2-Dibromoethane (4.69 g, 0.025 mol), *ortho*-hydroxyacetophenone (6.8 g, 0.05 mol), Na_2CO_3 (5.3 g, 0.05 mol) and DMF (45 ml) were stirred for 60 h at 95°C. The mixture was cooled with ice (70 g) and acidified with HCl (2 N, 20 ml). The crude product was collected by filtration and dissolved in $CHCl_3$. The solution was dried with Al_2O_3 (5 g) and recrystallized from acetone to give **3e**, 5.26 g (71%), mp 120–121°C; IR $\nu = 2953$, 1676, 1472, 1242, 1043 cm^{-1}; ^{1}H-NMR: 400 MHz ($CDCl_3$/TMS) $\delta = 2.59$ (6H, s, Ac), 4.48, (4H, s, OC_2H_4O), 7.04 (4H, m, Ar), 7.48 (2H, m, Ar), 7.73 (2H, m, Ar); ^{13}C-NMR 100 MHz ($CDCl_3$/TMS) $\delta = 67.7$, 113.5, 131.8, 122.5, 134.8, 158.9, 130.0, 208.0, 32.4; MW 298.34 for $C_{18}H_{18}O_4$; EI MS m/z 298.2, 257.2, 241.2, 181.2, 91.2, 77.2.

3.6. *1,2-bis(4-Acetylphenoxy)ethane* (**3f**)

1,2-Dibromoethane (4.69 g, 0.025 mol), 4-hydroxyacetophenone (6.8 g, 0.05 mol) and Na_2CO_3 (5.30 g, 0.050 mol) and DMF (45 ml) were stirred for 140 h at 95°C. The reaction mixture was subjected to the work up described for **3e** and the crude product was recrystallized from THF to give **3f**, 2.09 g (28%), mp 115°C; IR $\nu = 2954$, 2884, 1672, 1249, 1166, 1043 cm^{-1}; ^{1}H-NMR 400 MHz (DMSO-d_6/TMS) $\delta = 2.51$(6H, s, Ac), 4.41 (4H, s, OC_2H_4O), 6.97 (4H, d, $J = 8.7$, Ar), 7.90 (4H, d, $J = 8.7$, Ar); ^{13}C-NMR 100 MHz (DMSO-d_6/TMS) $\delta = 67.7$, 115.1, 127.0, 131.3, 157.0, 194.0, 26.5; MW 298.39 for $C_{18}H_{18}O_4$; EI MS m/z 298.6, 163.4, 121.2, 92.2, 77.2.

3.7. *1,2-bis(2-Acetylphenoxy)-3-oxapentane* (**3g**)

β, β'-Dichlorodiethylether (1.79 g, 0.0125 mol), 2-hydroxyacetophenone (3.4 g, 0.025 mol) and NaOH (1 g, 0.025 mol) and DMF (25 ml) were stirred for 100 h at 95°C. The reaction mixture was subjected to the work up described for **3f** and the crude product was recrystallized from Et2O to give **3g**, 1.68 g (30%), mp 51°C; IR $\nu = 2953$, 2902, 1676, 1600, 1497, 1370, 1063 cm^{-1}; ^{1}H-NMR 400 MHz ($CDCl_3$/TMS) $\delta = 2.51$ (6H,s,Ac), 3.90 (4H,t,J = 4.5,CH_2O), 4.22 (4H, *t*, $J = 4.5$, CH_2O), 7.02 (4H, m, Ar), 7.47 (2H, m, Ar), 7.75 (2H, m, Ar); ^{13}C-NMR 100 MHz ($CDCl_3$/TMS) $\delta = 70.6$, 69.4, 113.5, 131.7, 122.5, 134.8, 158.9, 130.0, 208.0, 32.4; MW 342.39 for $C_{20}H_{22}O_5$; EI MS *m*/*z* 342.6, 207.4, 163.3, 121.2, 91.1, 77.2.

3.8. *1,2-bis(4-Acetylphenoxy)-3-oxapentane* (**3h**)

β, β'-Dichlorodiethylether (3.58 g, 0.025 mol), 4-hydroxyacetophenone, (6.8 g, 0.05 mol) and Na_2CO_3 (5.3 g, 0.05 mol) and DMF (60 ml) were stirred for 140 h at 95°C. The reaction mixture was subjected to the work up described for **3g** and the crude product was recrystallized from Et_2O to give **3h**, 6.41 g (75%), mp 101°C; IR $\nu = 2942$, 1675, 1599, 1419, 1054, 956 cm^{-1}; ^{1}H-NMR 400 MHz (DMSO-d_6/TMS) $\delta = 2.51$ (6H, s, Ac), 3.91 (4H, *t*, $J = 4.5$, CH_2O), 4.22 (4H, *t*, $J = 4.5$, CH_2O), 6.97 (4H, d, $J = 8.7$, Ar), 7.89 (4H, d, $J = 8.7$, Ar); ^{13}C-NMR 100 MHz (DMSO-d_6/TMS) $\delta = 68.2$, 69.9, 115.1, 127.1, 131.3, 157.7, 194.3, 26.5; MW 342.39 for $C_{20}H_{22}O_5$; EI MS *m*/*z* 342.6, 207.4, 163.3, 121.2, 91.1, 77.2.

3.9. *1,2-bis(2-Hydroxyphenoxy)ethane* (**4a**)

HOAc (10 ml, 99%) and **3e** (0.42 g, 0.014 mol) were mixed at 40°C in a flask (100 ml) and a mixture of 33% H_2O_2 (1.15 ml, 0.011 mol) and HOAc (3 ml, 99%) was gradually added. The reaction was stirred for 4 days at 40°C then left overnight at room temperature, neutralized with NaOH (1 N, 10 ml) and crystallized from $CHCl_3$. This gave **4a**, 0.21 g (62%), mp 114°C; IR $\nu = 3463$, 2928, 1597, 1463, 1271, 1067 cm^{-1}; ^{1}H-NMR 400 MHz ($CDCl_3$/TMS) $\delta = 4.41$ (4H, s, C_2H_4O), 6.94 (8H, m, Ar) 10.19 (2H, s, OH); ^{13}C-NMR 100 MHz ($CDCl_3$/TMS) $\delta = 70.1$, 115.1, 117.4, 122.3, 124.7, 147.5, 148.3; MW 246.26 for $C_{14}H_{14}O_4$; EI MS *m*/*z* 246.2, 154.1, 136.1.

Acknowledgements

This work was supported by research funds from ITU, and spectral data were kindly supplied by TUBITAK (project TABG-1681).

References

[1] Grothens AM, Smid J, de Boer E. J Mag Res 1972;6:612.
[2] Vögtle F, Weber E. Angew Chem Int Ed Engl 1979;18:753.
[3] Tümmler B, Maas G, Weber E, Vögtle F. J Amer Chem Soc 1977;99:4683.
[4] Grand J, Lazslo P, Offermann W, Rinaldi PL. J Am Chem Soc 1981;103:1380.
[5] Valeur B, Pouget J, Bourson J, Kaschke M, Ernsting NP. J Phys Chem 1992;96:6545.
[6] Erk Ç. Polymer Bull 1980;2:445.
[7] Erk Ç. Polymer Bull 1983;10:315.
[8] Hoşgören H, Erk Ç. Polymer Bull 1981;4:47.
[9] Karslı N, Erk Ç. Dyes and Pigments 1996;32:61.
[10] Tuncer H, Erk Ç. Abstracts, 7th Int. Symp. Macromolecule-Metal Complexes. Holland: Leiden, 1997.
[11] Tuncer H, Erk Ç. In: A. W. Colleman (Ed.), Molecular Recognition and Inclusion. Kluwer, 1998, p. 531.
[12] Atwood JL. In: Y. Inoue, G. W. Gokel (Eds.), Cation Binding by Macrocycles. Basel, Marcel Dekker, 1990. p. 581.

[13] Erk Ç. Makromolekulare Chem Rapid Cummun 1984;5:269.

[14] Göçmen A, Bulut M, Erk Ç. Pure Appl Chem 1993;5:447.

[15] Göçmen A, Erk Ç. Fresenius J Anal Chem 1993;347:471.

[16] Göçmen A, Erk Ç. J Incl Phen 1996;26:67.

[17] Pretsch EM, Badertscher M, Welti M, Maruizumi T, Morf WE, Simon W. Pure Appl Chem 1988;80:567.

[18] Thomas JDR. Analyst 1991;116:1211.

[19] Denney RC. Named Organic Reactions. New York: Plenum Press, 1969. p. 177.