Pergamon

Tetrahedron 55 (1999) 3923–3930

TETRAHEDRON

Branched Non-covalent Complexes from Carboxylic Acids and a Tris(tetrahydropyrimidine) Base

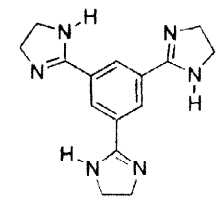
Arno Kraft* and Anja Reichert

Institut für Organische Chemie und Makromolekulare Chemie II, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, D-40225 Düsseldorf, Germany

Received 25 January 1999; accepted 2 February 1999

Abstract: Non-covalent binding of various carboxylic acids to 1,3,5-tris(1,4,5,6-tetrahydropyrimidin-2-yl)benzene **3** produced 3 : 1 complexes with good solubility in various non-polar organic solvents. The association constant for a model system was measured to be 61700 ± 11900 M^{-1} in $CD_3OD/CDCl_3$ (97 : 3), indicating the utility of this interaction between an acid and tri-basic heterocyclic amidine **3** for assembling branched complexes.

As a number of groups have shown recently, self-assembly provides a simple way towards the formation of defined, even complex, non-covalently linked structures in solution without the need for multi-step syntheses and lengthy purification procedures.[1] Since our initial report on branched 3 : 1 complexes between carboxylic acids and tris(imidazoline) **1**,[2] we wondered how another easily accessible amidine base, such as a tetrahydropyrimidine, would affect binding properties. Like imidazolines, tetrahydropyrimidines are basic[3] functional groups occasionally used in the design of drugs[4] or supramolecular receptors.[5] With regard to the heterocyclic amidine's ability to make complexes with carboxylic acids, Hosseini and coworkers have already demonstrated by a number of x-ray crystal structure studies that dicarboxylic acids and 1,2-bis(2-tetrahydropyrimidyl)ethane are capable of forming hydrogen-bonded networks in the solid state.[6]

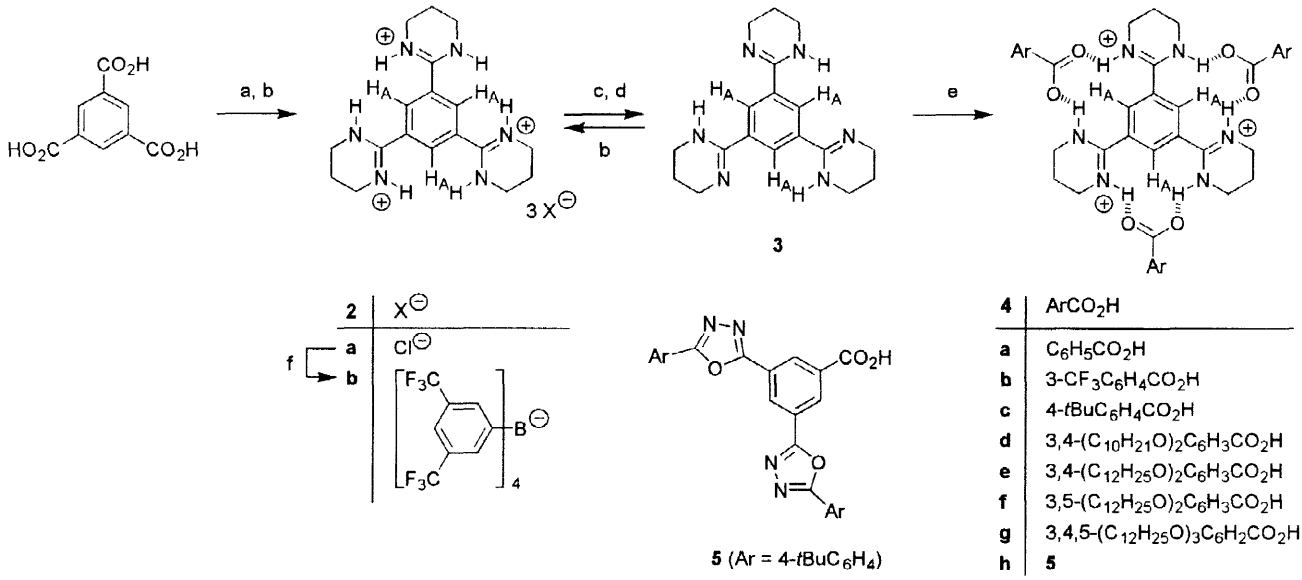


1

For the preparation of the tetrahydropyrimidine derivative, we adapted a route similar to our previous synthesis of **1**.[2] Hydrochloride **2a** was thus obtained in a single step from 1,3,5-benzenetricarboxylic acid and 1,3-diaminopropane in boiling ethylene glycol under acid catalysis (Scheme 1). Treatment with aqueous NaOH

0040-4020/99/$ - see front matter
PII: S0040-4020(99)00112-X

and gradient sublimation furnished the free base **3** as a light yellow solid in high purity. When **3** and 3 equiv. of a carboxylic acid were dissolved in a suitable polar solvent (usually hot EtOH or MeOH/MeCN), the 1 : 3 salt crystallised upon cooling, if necessary, after evaporation of some of the solvent. The resulting complexes **4** were analytically pure (although a number of complexes were prone to include water and had to be rigorously dried). New compounds were characterised by ^1H and ^{13}C NMR, IR, elemental analysis and differential scanning calorimetry (DSC). Complexes **4b–g**, less so **4a**, showed excellent solubility in $CHCl_3$ or toluene, typically in excess of 50 mg/mL. Complexes **4d–g** with their long alkoxy solubilising groups even dissolved in hexane.



Scheme 1. a) $H_2N\text{-}CH_2CH_2CH_2\text{-}NH_2$, $H_2N\text{-}CH_2CH_2CH_2\text{-}NH_2 \times 2$ HCl, *p*-TsOH, ethylene glycol, reflux, 3 h; b) HCl; c) NaOH; d) sublimation (310 °C/10^{-4} mbar), 33 – 64 %; e) $ArCO_2H$, MeOH, reflux, 32 – 87 %; f) $NaB[3,5\text{-}(CF_3)_2C_6H_3]_4$, CH_3CN, 74 %.

^1H NMR spectra of, for example, **2a** or **4a–c** in polar solvents, such as CD_3OD or DMSO-d_6, showed a singlet for the aromatic H_A protons at $\delta \approx 8.2 - 8.5$. Similarly, **2b** with the non-coordinating tetrakis[3,5-bis(trifluoromethyl)phenyl]borate counter-anion gave rise to an H_A signal at $\delta = 7.96$ and an NH singlet at $\delta = 8.5$ in $CDCl_3/CD_3CN$ (6 : 1). Both the H_A and NH signals shifted downfield in the presence of benzoate (Figure 1). In neat $CDCl_3$, the H_A resonance of carboxylic acid complexes **4a–h** was typically found at $\delta \approx 9.6 - 9.8$ and the NH singlet at $\delta \approx 12 - 13$ (Figure 2).[7] These substantial downfield shifts are attributed to hydrogen bonding of the carboxylate anion to two tetrahydropyrimidine NH groups in a bridged arrangement similar to complexes of **1**.[2] The dipole field induced by the carboxylate–tetrahydropyrimidinium ion pairs and/or close carboxylate-O···H_A contacts then explain such an unusual chemical shift for an aromatic proton. A chemical shift of $\delta < 8.5$ for the H_A signal implies the absence of complexation in polar solvents.

The number average molar mass of **4d**, determined by vapour-pressure osmometry in $CHCl_3$ at 34 °C, was 1300 g mol^{-1} which is within the experimental error close to the calculated molar mass of 1628 g mol^{-1}. A 3 : 1 complex stoichiometry was also confirmed by Job's method of continuous variation[8] (Figure 3).

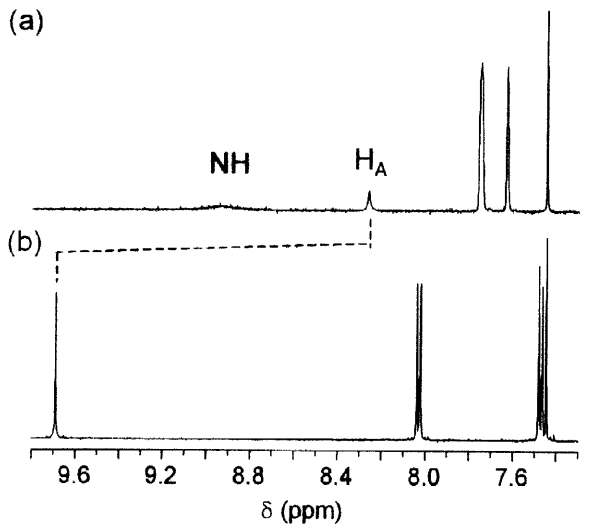


Figure 1. ^{1}H NMR spectra (500 MHz, $CDCl_3/CD_3CN$, 6 : 1) of (a) **2b** and of (b) *tert*-butylbenzoic acid complex **4c**.

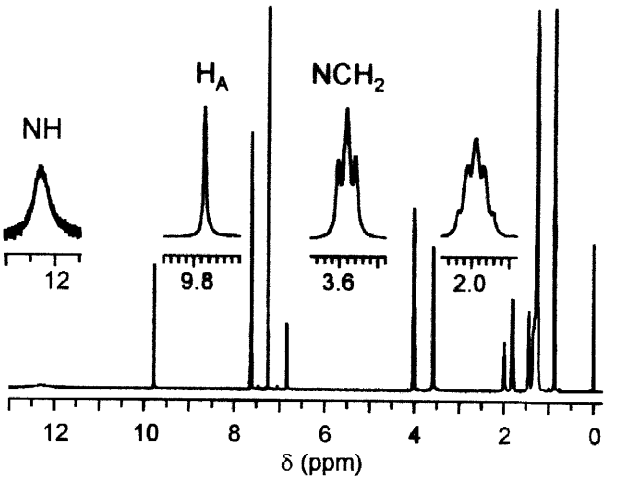
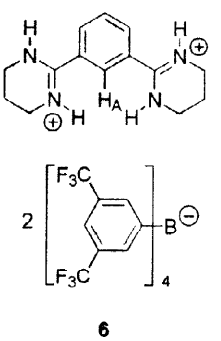


Figure 2. ^{1}H NMR spectrum (500 MHz, $CDCl_3$) of **4d**; the tetrahydropyrimidine signals are displayed as insets.

Since binding constants for 3 : 1 complexes are difficult to obtain, we decided to use a model system. The binding of a carboxylate between two tetrahydropyrimidinium groups was investigated by ^{1}H NMR dilution studies[9] of an equimolar mixture of **6** (derived from isophthalic acid in three steps) and tetramethylammonium benzoate. The hyperbolic concentration dependence of the H_A resonance of the **6**/$PhCO_2^-$ complex allowed us to calculate an association constant K_a of 61700 ± 11900 M^{-1} in the competitive solvent mixture $CDCl_3/CD_3OD$ (97 : 3) (Figure 4). This association constant was considerably larger than for a comparable bis(imidazoline) system[2] (990 ± 230 M^{-1}) indicating improved binding by the bis(tetrahydropyrimidine).



6

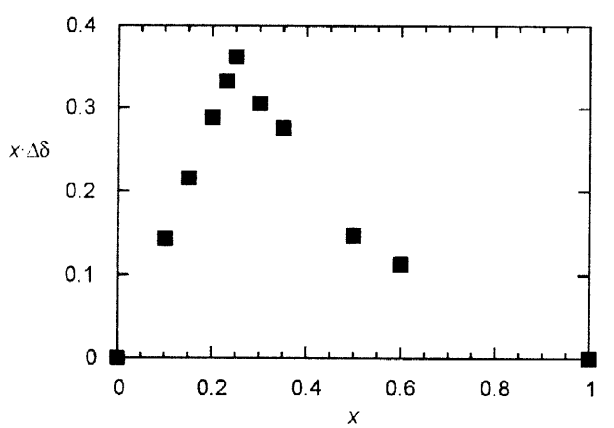


Figure 3. Job plot of **2b** and tetramethylammonium benzoate in $CDCl_3/CD_3CN$ (6 : 1) based on the change of $\delta(H_A)$ with the mole fraction x of **2b**. A maximum at x = 0.25 indicates that a 3 : 1 complex is indeed formed.

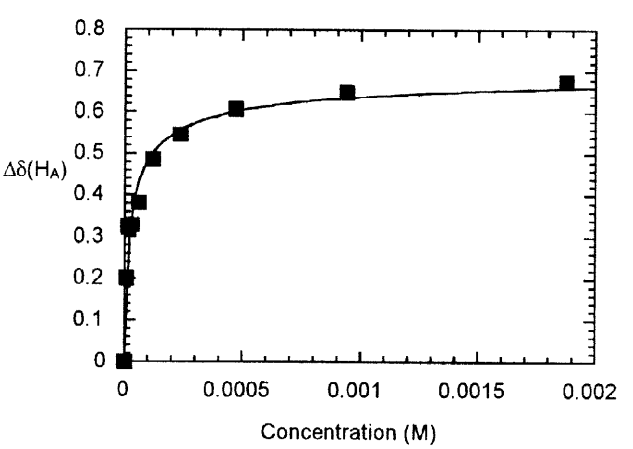


Figure 4. Changes of the chemical shift of the H_A signal upon dilution of an equimolar solution of **6** and tetramethylammonium benzoate in $CDCl_3/CD_3OD$ (97 : 3) at 25 °C.

Self-association was not observed for chloroform solutions of any of the complexes **4**, even if the benzoic acid derivative possessed an extended π-system (as in **4h**). At concentrations of about 1 weight%, solutions of **4d–g** in hexane gelled reversibly upon cooling to –20 °C, suggesting some interaction between molecules in non-polar hydrocarbons. Self-association in cyclohexane-d_{12} was evident from line-broadening of all the ^{1}H NMR signals of **4f** that became more pronounced with increasing concentration and decreasing temperature (Figure 5). Small up-field shifts for signals of protons near the core attested a certain, albeit only minor, contribution of π-stacking interactions between aromatic groups under these conditions. More likely, the driving force for self-association is the incompatibility of the complex's polar core with the lipophilic side chains and the solvent, similar to the phenomenon of microsegregation[10] in certain liquid-crystalline materials and block copolymers.

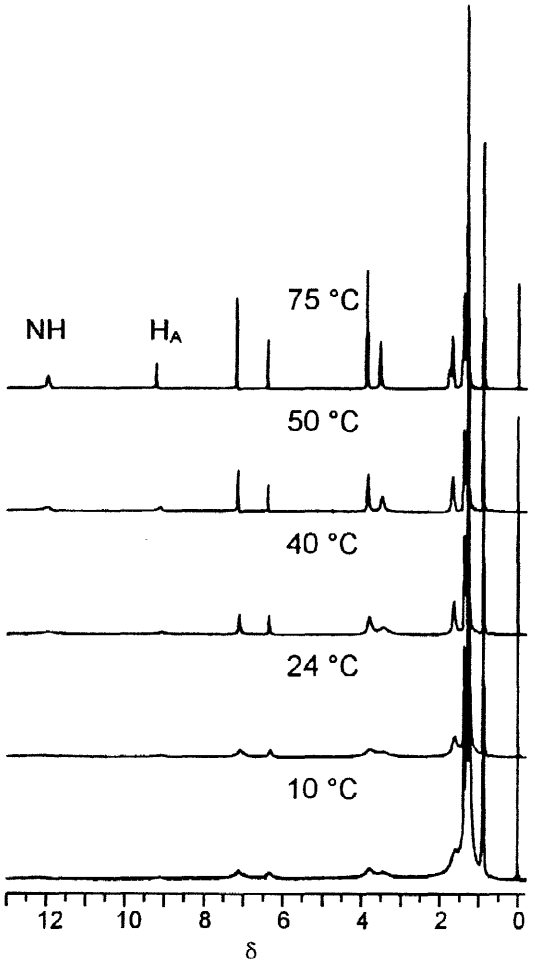


Figure 5. ^{1}H NMR spectrum (300 MHz, C_6D_{12}, 28 mg/mL) of **4f** at various temperatures.

All benzoic acid complexes (**4a–h**) showed a transition to a liquid-crystalline mesophase as evidenced by DSC and polarisation optical microscope studies. Although decomposition occurred in all cases upon prolonged heating, complexes with mesogenic benzoic acids could be kept just below the isotropisation temperature for several hours. Upon cooling from the isotropic melt, most complexes solidified to amorphous glasses. The super-cooled isotropic liquid of complex **4g** exhibited dendritic growth of homeotropic fingerlike contours (when viewed with parallel polarisers) that are characteristic of columnar mesophase formation. A further decrease in temperature and annealing gave focal-conic fan-like textures for **4f** and **4g**. These findings are particularly interesting in the light of recent reports on hydrogen-bonded columnar liquid-crystalline systems.[11]

The results described in this paper demonstrate complexation of carboxylic acids with tri-basic **3**. Further work towards the preparation of liquid-crystalline complexes and the formation of ordered supramolecular assemblies in solution is currently in progress.

Acknowledgement. We thank the Deutsche Forschungsgemeinschaft for financial support, Prof. Dr. G. Wulff for his interest, and Ms S. Johann for assistance in the preparation of starting materials.

EXPERIMENTAL

General methods. All solvents were distilled prior to use. Melting points: Olympus BH-2 polarisation microscope with a Linkam TMS91 hot stage. DSC: Mettler DSC 30 with TC 11/TA 4000 Processor (10 °C min^{-1}; K: crystalline phase, X: unidentified phase transition, M: liquid-crystalline mesophase, I: isotropic liquid). NMR: Varian VXR 300, Bruker DRX 500. TMS was used as internal standard in the NMR measurements. Multiplicities of ^{13}C signals were determined by DEPT experiments. IR: Bruker Vector 22 FT-IR. EI-MS: Varian MAT 311 A (70 eV). CI-MS: Finnigan INCOS 50. Elemental analyses: Pharmaceutical Institute of the Heinrich Heine University, Düsseldorf. VPO measurements were performed with a Knauer vapour-pressure osmometer in $CHCl_3$ at 35 °C against benzil or polystyrene standards (Fluka, Switzerland) as reference. The number-average molar mass M_n was determined for solutions in a concentration range between 9 and 25 mg g^{-1}. Sodium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate,[12] 3,4-bis(decyloxy)benzoic acid,[13] 3,4- and 3,5-bis(dodecyloxy)benzoic acid,[14,15] 3,4,5-tris(dodecyloxy)benzoic acid[16] and **5**[17] were prepared as described in the literature.

1,3,5-Tris(3,4,5,6-tetrahydropyrimidin-2-yl)benzene (3). Benzene-1,3,5-tricarboxylic acid (2.92 g, 13.9 mmol), 1,3-diaminopropane (3.7 mL, 50 mmol), 1,3-diaminopropane dihydrochloride (50 mmol, prepared by freeze-drying a solution of 3.7 mL of 1,3-diaminopropane in 10 mL of conc. HCl), *p*-toluenesulfonic acid (208 mg, 1.09 mmol) and ethylene glycol (20 mL) were heated to reflux for 3 h. About half of the ethylene glycol was then slowly removed by distillation. The yellowish solution was concentrated to dryness at reduced pressure (70 °C/0.02 mbar). The residual brown oil was dissolved in water (50 mL). Addition of aqueous NaOH (5.0 g/10 mL) gave a yellow precipitate that was collected by suction filtration, washed with water (20 mL), once more dissolved in water (50 mL)/conc. HCl (3 mL) and precipitated by the addition of ice-cold aqueous NaOH (5.0 g/10 mL). Gradient sublimation (310 °C/10^{-4} mbar) of the crude product (4.08 g) gave **3** as a yellow solid (2.34 g, 52 %): M.p. 425 – 426 °C (decomp.); ^1H NMR (500 MHz, CD_3OD): δ 1.86 (qui, J = 5.8 Hz; CH_2), 3.45 (t, J = 5.8 Hz; NCH_2), 7.91 (s; H_A); IR (KBr, cm^{-1}): ν 3214 (s), 1619 (s), 1524 (s), 1360 (m), 1284 (m); MS (CI, NH_3): *m/z* 326, 325 ($M + H^+$, 20, 100 %); $C_{18}H_{24}N_6$ (324.43): calcd. C 66.64, H 7.46, N 25.90; found C 66.49, H 7.55, N 26.12. Trihydrochloride **2a** was obtained in quantitative yield after freeze-drying a solution of **3** in conc. HCl: Decomp. > 360 °C; ^1H NMR (500 MHz, CD_3OD): δ 2.16 (qui, J = 5.8 Hz; CH_2), 3.68 (t, J = 5.8 Hz; NCH_2), 8.43 (s; H_A); ^1H NMR (300 MHz, D_2O): δ 2.16 (qui, J = 5.8 Hz; CH_2), 3.66 (t, J = 5.8 Hz; NCH_2), 8.27 (s; H_A); ^{13}C NMR (75 MHz, D_2O): δ 18.4 (CH_2), 40.4 (NCH_2), 131.9 (C_6H_3), 132.2 (*ipso*-C), 159.6 (C=N); IR (KBr, cm^{-1}): ν 3394 (s), 3168 (s), 3027 (s), 1661 (s), 1596 (m), 1371 (m), 1312 (m); $C_{18}H_{27}Cl_3N_6 \times H_2O$: calcd. C 47.85, H 6.47, N 18.60; found C 47.90, H 6.40, N 18.53. For the preparation of **2b**, a solution of **2a** (23.8 mg, 0.0526 mmol) and $NaB[3,5\text{-}(CF_3)_2C_6H_3]_4$ (140 mg, 0.158 mmol) in CH_3CN (5 mL)/water (1 mL) was concentrated in vacuum. The residue was then taken up in CH_3CN (2 mL)/$CHCl_3$ (2 mL), membrane-filtered and concentrated again in vacuum. Drying at 80 °C/10^{-5} mbar furnished **2b** (113 mg, 73 %) as a brown amorphous powder: ^1H NMR (500 MHz, $CDCl_3/CD_3CN$, 6 : 1): δ 2.11 (qui, J = 5.8 Hz; CH_2), 3.62 (t, J = 5.8 Hz; NCH_2), 7.54 (br. s, 9 H), 7.67 [br. m, 18 H; $(CF_3)_2C_6H_3$], 8.22 (s; H_A), 8.9 (br. s, NH); IR (KBr, cm^{-1}): ν 1661 (m), 1357 (s), 1279 (s), 1125 (s), 713 (m), 683 (m), 670 (m); $C_{114}H_{63}B_3F_{72}N_6 \times 2\ H_2O$: calcd. C 46.37, H 2.29, N 2.85; found C 46.20, H 2.40, N 3.16.

1,3-Bis(3,4,5,6-tetrahydropyrimidin-2-yl)benzene. The synthesis was carried out as described for **3** with isophthalic acid, 1,3-diaminopropane and 1,3-diaminopropane dihydrochloride. Sublimation (240 °C/0.1 mbar) gave an ochre solid. Yield: 51 %; m.p. 239 – 243 °C (decomp.); ^1H NMR (300 MHz, CD_3OD): δ 1.83 (≈qui, J = 5.7 Hz; CH_2), 3.42 (t, J = 5.7 Hz; NCH_2), 7.41 (t, J = 7.7 Hz, 1 H), 7.66 (dd, J = 7.7, 1.9 Hz, 2 H), 7.84 (t, J =

1.9 Hz, 1 H; C_6H_4); ^{13}C NMR (75 MHz, CD_3OD): δ 21.5 (CH_2), 42.8 (NCH_2), 126.0, 129.2, 129.4 (arom. CH), 138.4, 158.1 (*ipso*-C, C=N); IR (KBr, cm^{-1}): ν 3193 (m), 2923 (m), 2837 (m), 1619 (s), 1600 (m), 1550 (m), 1363 (m), 1305 (m), 1300 (m); MS (EI): *m/z* 243, 241 (M^+, 48, 48 %), 214 (23), 186, 184 (100, 38), 129 (90), 102 (49); $C_{14}H_{18}N_4$ (242.32): calcd. C 69.39, H 7.49, N 23.12; found C 69.24, H 7.47, N 23.15. 1,3-Bis(3,4,5,6-tetrahydropyrimidin-2-yl)benzene dihydrochloride was prepared as described for **2a**: Amorphous solid; ^1H NMR (300 MHz, D_2O): δ 2.14 (≈qui, J = 5.8 Hz; CH_2), 3.63 (t, J = 5.8 Hz; NCH_2), 7.81 (≈t, 1 H), 7.96 – 8.01 (ABX, 3 H; C_6H_4); IR (KBr, cm^{-1}): ν 3146 (s), 3004 (s), 1651 (s), 1315 (m), 699 (m); $C_{14}H_{20}Cl_2N_4 \times 2\ H_2O$: calcd. C 47.87, H 6.89, N 15.95; found C 47.70, H 6.71, N 15.80. **6**: Prepared analogously to **2b**. Yield: 81 %, amorphous solid; ^1H NMR (500 MHz, $CDCl_3/CD_3CN$, 6 : 1): δ 2.10 (≈qui, J = 5.8 Hz; CH_2), 3.59 (t, J = 5.8 Hz; NCH_2), 7.54 (br. s, 9 H), 7.67 [br. m, 18 H; $(CF_3)_2C_6H_3$], 7.75 (t, J = 7.7 Hz, 1 H), 7.86 (dd, J = 7.7, 1.9 Hz, 2 H), 7.96 (br. s, 1 H; C_6H_4), 8.54 (br. s; NH); IR (KBr, cm^{-1}): ν 1653 (m), 1355 (s), 1276 (s), 1126 (br. s), 886 (m), 839 (m), 713 (m), 682 (m), 671 (m); $C_{78}H_{44}B_2F_{48}N_4$: calcd. C 47.54, H 2.25, N 2.84; found C 47.25, H 2.30, N 2.94.

General procedure for the preparation of the complexes. Carboxylic acid (1.00 mmol) and **3** (0.333 mmol) were dissolved in hot methanol (*ca.* 40 mL). After filtration of the hot solution and concentration, the crude product was crystallised from the solvent (mixture) indicated for each complex.

Complex with benzoic acid (4a). Yield: 48 % (from MeCN/MeOH); DSC: K/221 °C (ΔH 14 J g^{-1})/M/253 °C (ΔH 61 J g^{-1})/I; ^1H NMR (500 MHz, $CDCl_3$): δ 2.00 (qui, J = 5.7 Hz; CH_2), 3.60 (t, J = 5.7 Hz; NCH_2), 7.34 – 7.43 (m, 3 H), 8.05 (m, 2 H; C_6H_5), 9.60 (s; H_A), 11.0 (br. s; NH); ^1H NMR (500 MHz, CD_3OD): δ 2.06 (qui, J = 5.7 Hz; CH_2), 3.60 (t, J = 5.7 Hz; NCH_2), 7.32 – 7.43 (m, 3 H), 7.87 (m, 2 H; C_6H_5), 8.30 (s; H_A); ^1H NMR (500 MHz, DMSO-d_6): δ 1.89 (qui, J = 5.7 Hz; CH_2), 3.49 (t, J = 5.7 Hz; NCH_2), 7.31 – 7.41 (m, 3 H), 7.87 (m, 2 H; C_6H_5), 8.52 (s; H_A), 11.0 (br. s; NH); IR (KBr, cm^{-1}): ν 2937 (m), 1653 (s), 1600 (s), 1553 (s), 1379 (s), 1317 (m), 722 (m); $C_{39}H_{42}N_6O_6 \times 2\ H_2O$: calcd. C 64.45, H 6.38, N 12.17; found C 64.25, H 6.28, N 11.42.

Complex with 3-trifluoromethylbenzoic acid (4b). Yield: 75 % (from MeCN/MeOH); DSC: K/209 °C (ΔH 78 J g^{-1})/M, decomp. above 280 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 2.06 (qui, J = 5.8 Hz; CH_2), 3.64 (t, J = 5.8 Hz; NCH_2), 7.48 (t, J = 7.7 Hz, 1 H), 7.68 (br. d, J = 7.7 Hz, 1 H), 8.22 (br. d, J = 7.7 Hz, 1 H), 8.32 (br. s, 1 H; $CF_3C_6H_4CO_2^-$), 9.67 (s; H_A), 12.1 (br. s; NH); ^1H NMR (500 MHz, C_6D_6): δ 0.82 (qui; CH_2), 2.83 (t; NCH_2), 7.17 (t, 1 H), 7.50 (br. d, 1 H), 8.72 (br. d, 1 H), 9.04 (br. s, 1 H; C_6H_4), 9.67 (s; H_A), 12.55 (br. s; NH); ^1H NMR (500 MHz, DMSO-d_6): δ 1.95 (qui; CH_2), 3.54 (t; NCH_2), 7.58 (t, 1 H), 7.74 (br. d, 1 H), 8.12 (br. d, 1 H), 8.13 (br. s, 1 H; C_6H_4), 8.56 (s; H_A); ^1H NMR (500 MHz, CD_3OD): δ 2.10 (qui; CH_2), 3.63 (t; NCH_2), 7.56 (t, 1 H), 7.71 (br. d, 1 H), 8.12 (br. d, 1 H), 8.18 (br. s, 1 H; C_6H_4), 8.39 (s; H_A); ^{13}C NMR (125 MHz, $CDCl_3$): δ 18.1 (CH_2), 39.7 (NCH_2), 124.3 (q, $^1J_{CF}$ = 272.2 Hz; CF_3), 126.3 (q, $^3J_{CF}$ = 3.9 Hz), 126.9 (q, $^3J_{CF}$ = 3.9 Hz), 128.3, 130.4, 132.6 (arom. CH), 130.23, 130.24 (q, $^2J_{CF}$ = 32.4 Hz), 132.6 (q, $^4J_{CF}$ = 1.2 Hz), 138.5, 156.9, 172.0 (*ipso*-C, C=N, C=O); IR (KBr, cm^{-1}): ν 1656 (s), 1601 (s), 1556 (s), 1386 (s), 1322 (s), 1124 (m), 773 (m), 691 (m); $C_{42}H_{39}F_9N_6O_6$: calcd. C 56.38, H 4.39, N 9.39; found C 56.28, H 4.22, N 9.10.

Complex with 4-*tert*-butylbenzoic acid (4c). Yield: 71 % (from MeCN/MeOH); DSC: K/148 °C (ΔH 177 J g^{-1})/M/217 °C (ΔH 34 J g^{-1})/M/287 °C (ΔH 50 J g^{-1})/I (decomp.); ^1H NMR (500 MHz, $CDCl_3$): δ 1.33 (s; CH_3), 2.00 (qui, J = 5.7 Hz; CH_2), 3.61 (t, J = 5.7 Hz; NCH_2), 7.38 and 7.98 (AA'XX'; C_6H_4), 9.76 (br. s; H_A), 12.2 (br. s; NH); ^1H NMR (500 MHz, C_6D_6): δ 0.82 (qui, J = 5.7 Hz; CH_2), 1.27 (s; CH_3), 2.90 (t, J = 5.7 Hz; NCH_2), 7.51 and 8.70 (AA'XX'; C_6H_4), 9.92 (br. s; H_A), 12.9 (br. s; NH); ^1H NMR (500 MHz, CD_3OD): δ 1.32 (s; CH_3), 2.05 (qui, J = 5.6 Hz; CH_2), 3.59 (t, J = 5.6 Hz; NCH_2), 7.39 and 7.80 (AA'XX'; C_6H_4), 8.33 (s; H_A); ^{13}C NMR (125 MHz, $CDCl_3$): δ 18.2 (CH_2), 31.3 (CH_3), 34.8 [$C(CH_3)_3$], 39.6 (NCH_2), 124.7, 129.2, 131.4 (C_6H_4), 130.1, 134.7, 153.5, 156.8, 173.8 (*ipso*-C, C=N, C=O); IR (KBr, cm^{-1}): ν 2963 (s), 1655 (s), 1603 (s), 1542 (m), 1381 (s), 1318 (m), 791 (m), 716 (m); $C_{51}H_{66}N_6O_6 \times 3\ H_2O$: calcd. C 68.43, H 7.88, N 9.39; found C 68.28, H 8.01, N 9.33.

Complex with 3,4-bis(decyloxy)benzoic acid (4d). Yield: 51 % (from EtOH); DSC: K/80 °C (ΔH 24 J g^{-1})/X/90 °C (ΔH 59 J g^{-1})/M/100 °C (ΔH 24 J g^{-1})/I; ^1H NMR (500 MHz, $CDCl_3$): δ 0.87 (≈t, 18 H; CH_3), 1.22 – 1.48 (m, 84 H), 1.78 – 1.85 (m, 12 H), 1.99 (qui, J = 5.7 Hz, 6 H; CH_2), 3.59 (t, J = 5.7 Hz, 12 H; NCH_2),

4.01 (t, J = 6.6 Hz, 12 H), 4.03 (t, 12 H; OCH_2), 6.84 (d, J = 8.7 Hz, 3 H), 7.62 – 7.65 (m, 6 H; $C_6H_3CO_2^-$), 9.79 (s; H_A), 12.3 (br. s; NH); ^{13}C NMR (125 MHz, $CDCl_3$): δ 18.2 (CH_3), 14.1, 22.7, 26.04, 26.08, 29.27, 29.36, 29.45, 29.48, 29.60, 29.61, 29.64, 29.66, 31.9, 39.7, 69.1, 69.3 (CH_2), 112.1, 114.9, 122.7, 131.4 (arom. CH), 130.0, 148.2, 151.2, 156.7, 157.7, 173.8 (*ipso*-C, C=N, C=O); IR (KBr, cm^{-1}): ν 2922 (s), 2852 (s), 1656 (m), 1601 (m), 1550 (m), 1380 (s), 784 (m); VPO ($CHCl_3$, 34 °C): M_n 1280 g mol^{-1} (against benzil as standard), 1350 g mol^{-1} (against polystyrene 2000 as standard); $C_{99}H_{162}N_6O_{12}$ (1628.40): calcd. C 73.02, H 10.03, N 5.16; found C 72.98, H 10.28, N 5.08.

Complex with 3,4-bis(dodecyloxy)benzoic acid (4e). Yield: 87 % (from EtOH); DSC: K/79 °C (ΔH 46 J g^{-1})/X/94 °C (ΔH 36 J g^{-1})/M/109 °C (ΔH 79 J g^{-1})/I; ^1H NMR (500 MHz, $CDCl_3$): δ 0.88 (≈t, 18 H; CH_3), 1.22 – 1.49 (m, 108 H), 1.78 – 1.85 (m, 12 H), 1.99 (qui, J = 5.7 Hz, 6 H; CH_2), 3.59 (t, J = 5.7 Hz, 12 H; NCH_2), 4.01 (t, J = 6.5 Hz, 6 H), 4.02 (t, 6 H; OCH_2), 6.84 (d, J = 8.8 Hz, 3 H), 7.62 – 7.64 (m, 6 H; $C_6H_3CO_2^-$), 9.76 (s; H_A), 12.3 (br. s; NH); IR (KBr, cm^{-1}): ν 2920 (s), 2851 (s), 1657 (m), 1601 (m), 1548 (m), 1468 (m), 1417 (m), 1377 (s), 1268 (s), 1216 (m), 760 (m); $C_{111}H_{186}N_6O_{12}$: calcd. C 74.20, H 10.43, N 4.68; found C 74.20, H 10.72, N 4.74.

Complex with 3,5-bis(dodecyloxy)benzoic acid (4f). Yield: 60 % (from EtOH), waxy solid; DSC: glass-transition at 59 °C/M/187 °C (ΔH 6 J g^{-1})/I; ^1H NMR (500 MHz, $CDCl_3$): δ 0.88 (t, J = 6.9 Hz, 18 H; CH_3), 1.22 – 1.46 (m, 108 H), 1.73 – 1.78 (m, 12 H), 2.00 (qui, J = 5.7 Hz, 6 H; CH_2), 3.60 (t, J = 5.7 Hz, 12 H; NCH_2), 3.96 (t, J = 6.5 Hz, 12 H), 6.52 (t, J = 2.4 Hz, 3 H), 7.21 (d, 6 H; $C_6H_3CO_2^-$), 9.75 (s; H_A), 12.2 (br. s; NH); IR (KBr, cm^{-1}): ν 2923 (s), 2853 (m), 1651 (m), 1594 (m), 1372 (m), 1159 (m); $C_{111}H_{186}N_6O_{12}$: calcd. C 74.20, H 10.43, N 4.68; found C 73.78, H 10.78, N 4.45.

Complex with 3,4,5-tris(dodecyloxy)benzoic acid (4g). Yield: 69 % (from EtOH); DSC: K/37 °C (ΔH 27 J g^{-1})/X/104/glass transition/205 °C (ΔH 6 J g^{-1})/I; ^1H NMR (500 MHz, $CDCl_3$): δ 0.88 (t, 27 H; CH_3), 1.22 – 1.50 (m, 162 H), 1.71 – 1.82 (m, 18 H), 1.98 (qui, J = 5.7 Hz, 6 H; CH_2), 3.58 (t, J = 5.7 Hz, 18 H; CH_2), 3.98 (t, J = 6.6 Hz, 6 H), 4.00 (t, J = 6.6 Hz, 12 H; OCH_2), 7.31 (s, 6 H; C_6H_2), 9.76 (s, 3 H; H_A), 12.2 (br. s, 6 H; NH); IR (KBr, cm^{-1}): ν 2921 (s), 2852 (s), 1657 (m), 1554 (m), 1374 (s), 1114 (m); $C_{147}H_{258}N_6O_{15}$: calcd. C 75.14, H 11.07, N 3.58; found C 74.92, H 11.18, N 3.33.

Complex with 3,5-bis[5-(4-*tert*-butylphenyl)-1,3,4-oxadiazol-2-yl]benzoic acid (4h). Yield: 32 % (from MeCN/MeOH); m.p. 310 – 311 °C (decomp.); ^1H NMR (500 MHz, $CDCl_3$): δ 1.38 (s, 54 H; CH_3), 2.16 (qui, J = 5.6 Hz, 6 H; CH_2), 3.80 (t, J = 5.6 Hz, 12 H; NCH_2), 7.57 and 8.11 (AA'XX'; C_6H_4), 8.90 (t, J = 1.7 Hz, 3 H), 8.97 (d, 6 H; C_6H_3), 9.68 (s, 3 H; H_A), 12.0 (br. s, 6 H; NH); IR (KBr, cm^{-1}): ν 2963 (s), 1653 (s), 1636 (s), 1617 (s), 1541 (s), 1495 (s), 1373 (m), 721 (m); $C_{111}H_{114}N_{18}O_{12} \times 3\ H_2O$: calcd. C 68.50, H 6.21, N 12.95; found C 68.29, H 6.15, N 12.73.

REFERENCES AND NOTES

1 Some recent examples include: (a) Yang, J. ; Marendaz, J.-L.; Geib, S. J.; Hamilton, A. D. *Tetrahedron Lett.* **1994**, *35*, 3665 – 3668; (b) Whitesides, G. M.; Simanek, E. E.; Mathias, J. P.; Seto, C. T.; Chin, D. N.; Mammen, M.; Gordon, D. M. *Acc. Chem. Res.* **1995**, *28*, 37 – 44; (c) Marsh, A.; Silvestri, M.; Lehn, J.-M. *Chem. Commun.* **1996**, 1527–1528; (d) Huck, W. T. S.; Hulst, R.; Timmerman, P.; van Veggel, F. C. J. M.; Reinhoudt, D. N. *Angew. Chem. Int. Ed. Engl.* **1997**, *36*, 1006 – 1008; (e) Zeng, F.; Zimmerman, S. C. *Chem. Rev.* **1997**, *97*, 1681–1712; (f) Stupp, S. I. *Macromol. Symp.* **1997**, *117*, 1 – 9; (g) Zimmerman, S. C.; Wang, Y.; Bharathi, P.; Moore, J. S. *J. Am. Chem. Soc.* **1998**, *120*, 2172 – 2173; (h) Percec, V.; Ahn, C.-H.; Ungar, G.; Yeardley, D. J. P.; Möller, M.; Sheiko, S. S. *Nature* **1998**, *391*, 161 – 164.

2 Kraft, A.; Fröhlich, R. *Chem. Commun.* **1998**, 1085 – 1086.

[3] The pK_a of 2-phenyl-1,4,5,6-tetrahydropyrimidine hydrochloride is 12.8 (Brown, D. J.; Evans, R. F. *J. Chem. Soc.* **1962**, 4039 – 4045), whereas protonated 2-phenylimidazoline has a pK_a of only 9.88 (Fernández, B.; Perillo, I.; Lamdan, S. *J. Chem. Soc., Perkin Trans. 2* **1973**, 1371 – 1374).

[4] Messer, W. S.; Abuh, Y. F.; Liu, Y.; Periyasamy, S.; Ngur, D. O.; Edgar, M. A. N.; ElAssadi, A. A.; Sbeih, S.; Dunbar, P. G.; Roknich, S.; Rho, T.; Fang, Z.; Ojo, B.; Zhang, H.; Huzl, J. J.; Nagy, P. I. *J. Med. Chem.* **1997**, *40*, 1230 – 1246.

[5] Dobashi, Y.; Kobayashi, K.; Sato, N.; Dobashi, A. *Tetrahedron Lett.* **1998**, *39*, 2985 – 2988.

[6] (a) Hosseini, M. W.; Ruppert, R.; Schaeffer, P.; De Cian, A.; Kyritsakas, N.; Fischer, J. *J. Chem. Soc. Chem. Commun.* **1994**, 2135 – 2136; (b) Brand, G.; Hosseini, M. W.; Ruppert, R.; De Cian, A.; Fischer, J.; Kyritsakas, N. *New. J. Chem.* **1995**, *19*, 9 – 13; (c) Félix, O.; Hosseini, M. W.; De Cian, A.; Fischer, J. *Tetrahedron Lett.* **1997**, *38*, 1755 – 1758; (d) Félix, O.; Hosseini, M. W.; De Cian, A.; Fischer, J. *Tetrahedron Lett.* **1997**, *38*, 1933 – 1936; (e) Félix, O.; Hosseini, M. W.; De Cian, A.; Fischer, J. *Angew. Chem. Int. Ed. Engl.* **1997**, *36*, 102 – 104.

[7] The corresponding H_A signal of carboxylic acid complexes of **1** is found at even lower field ($\delta \approx 10.1$).[2] The slightly reduced H_A chemical shift observed for complexes of **3** may be attributed to the fact that, unlike imidazoline, the six-membered heterocycle in 2-aryltetrahydropyrimidines has a tendency to twist out of the plane of an adjacent phenyl ring.[6b]

[8] (a) Job, P. *Ann. Chim.* **1928**, *9*, 113 – 203; (b) Blanda, M. T.; Horner, J. H.; Newcomb, M. *J. Org. Chem.* **1989**, *54*, 4626 – 4636.

[9] (a) Wilcox, C. S. in *Frontiers in Supramolecular Chemistry and Photochemistry* (Schneider, H.-J.; Dürr, H., Eds.), VCH, Weinheim, 1991, pp. 123 – 143; (b) Macomber, R. S. *J. Chem. Educ.* **1992**, *69*, 375 – 378.

[10] Tschierske, C. *J. Mater. Chem.* **1998**, *8*, 1485 – 1508.

[11] (a) Kleppinger, R.; Lillya, C. P.; Yang, C. *J. Am. Chem. Soc.* **1997**, *119*, 4097 – 4102; (b) Goldmann, D.; Dietel, R.; Janietz, D.; Schmidt, C.; Wendorff, J. H. *Liq. Cryst.* **1998**, *24*, 407 – 411; (c) Suárez, M.; Lehn, J.-M.; Zimmerman, S. C.; Skoulios, A.; Heinrich, B. *J. Am. Chem. Soc.* **1998**, *120*, 9526 – 9532.

[12] Nishida, H.; Takada, N.; Yoshimura, M.; Sonoda, T.; Kobayashi, H. *Bull. Chem. Soc. Jpn.* 1984, **57**, 2600 – 2604.

[13] Tuffin, R. P.; Toyne, K.J.; Goodby, J. W. *J. Mater. Chem.* **1996**, *6*, 1271 – 1282.

[14] Cukiernik, F. D.; Ibn-Elhaj, M.; Chaia, Z. D.; Marchon, J.-C.; Giroud-Godquin, A.-M.; Guillon, D.; Skoulios, A.; Maldivi, P. *Chem. Mater.* **1998**, *10*, 83 – 91.

[15] Zerban, G; Meier, H. *Z.Naturforsch. B* **1993**, *48*, 171 – 184.

[16] Meier, H.; Prass, E.; Zerban, G.; Kosteyn, F. *Z. Naturforsch. B* **1988**, *43*, 889 – 896.

[17] Kraft, A. *Liebigs Ann./Recueil* **1997**, 1463 – 1471.