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Host compounds (+)-(2*R*,3*R*)-1,1,4,4-tetraphenylbutane-1,2,3,4-tetraol (**TETROL**) and (2*R*,3*R*)-(−)-2,3-dimethoxy-1,1,4,4-tetraphenylbutane-1,4-diol (**DMT**) with guests *o*-, *m*- and *p*- toluidine: A comparative investigation

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ABSTRACT

In this work, we have compared the host abilities of closely related compounds (+)-(2*R*,3*R*)-1,1,4,4-tetraphenylbutane-1,2,3,4-tetraol (**TETROL**) and (2*R*,3*R*)-(−)-2,3-dimethoxy-1,1,4,4-tetraphenylbutane-1,4-diol (**DMT**) when these were recrystallized from single and mixed toluidine guests. Significant differences in host behaviour and selectivities were revealed and these were explained by means of single crystal diffraction experiments. Thermal analyses were used to determine the relative complex stabilities, and these data correlated exactly with the host selectivity orders for both **TETROL** and **DMT**.

1. Introduction

Host-guest chemistry is that field of supramolecular chemistry[1] in which host compounds, in the presence of particular guests, are able to enclathrate these and, in so doing, form complexes with them. Typically, the host material is a crystalline solid, while the guests may be gases, liquids or solids, but more usually liquids. Host-guest complexes are ordinarily held together by means of non-covalent interactions such as van der Waals attractive forces, π−π and CH−π interactions, ion pairing and hydrogen bonding.[2]

There have been a number of proposed general structures for the design of novel and effective host compounds,[3–7] and it is possible to summarise the more salient characteristics of these. Successful host compounds oftentimes (i) have hydrogen bonding capabilities in order to stabilize the host−guest interaction, (ii) have bulky, hydrophobic substituents (such as aromatic moieties) that provide a *surrounding factor* which surround the guest molecules in the crystal, (iii) are crystalline to facilitate separation of the guest from the host, and (iv) have rigid frameworks which contribute towards their crystallinity.

The number of literature reports each year covering aspects of host-guest chemistry is overwhelming as chemists attempt to understand better the underlying principles involved. Not only this, but host-guest chemistry has a myriad useful applications in the chemistry realm. Host compounds are able to serve as separation agents for racemates[8] as well as structural isomers,[9–14] and have been utilized in modified stationary phases for chromatographic applications.[15] Furthermore, host materials find application in both chemosensors and biosensors,[16–18] while optically pure host compounds often find further use as catalysts in asymmetric syntheses, as demonstrated by the TADDOL class of compounds.[15]

Our research team focuses on the employment of host compounds for the separation of structural isomers, which is ordinarily quite difficult to achieve by conventional means owing to their similar physical properties. During these investigations, we found that both (+)-(2*R*,3*R*)-1,1,4,4-tetraphenylbutane-1,2,3,4-tetraol (**TETROL**) and a dimethoxy derivative thereof, (2*R*,3*R*)-(−)-2,3-dimethoxy-1,1,4,4-tetraphenylbutane-1,4-diol (**DMT**), have the ability to form inclusion complexes with selected toluidine (methylaniline) isomers [*o*-toluidine (***o*-TOL**), *m*-toluidine (***m*-TOL**) and *p*-toluidine (***p*-TOL**)], the boiling points of which range between 200 and 203 °C (Scheme 1). The toluidines are important

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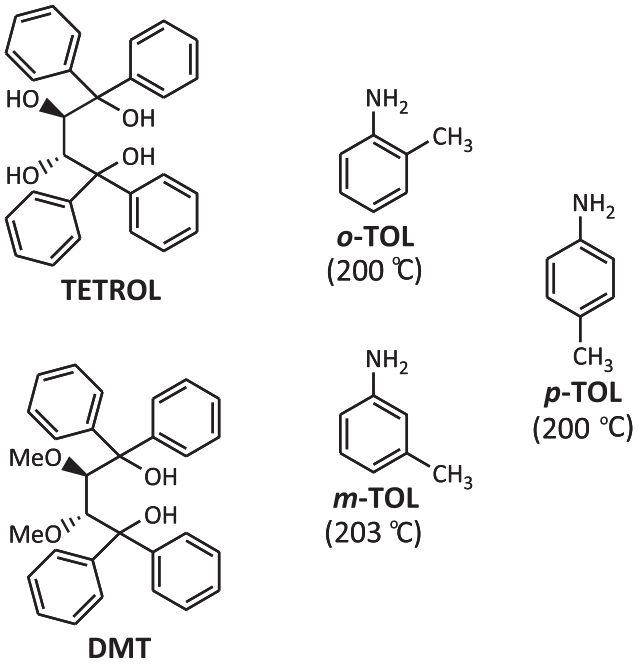

Scheme 1. Structures of host compounds (+)-(2*R*,3*R*)-1,1,4,4-tetraphenylbutane-1,2,3,4-tetraol (**TETROL**) and (2*R*,3*R*)-(−)-2,3-dimethoxy-1,1,4,4-tetraphenylbutane-1,4-diol (**DMT**), and guests *o*-toluidine (***o*-TOL**), *m*-toluidine (***m*-TOL**) and *p*-toluidine (***p*-TOL**). In brackets beneath each guest structure is listed its boiling point.

industrial chemicals in that they are predominantly used as solvents and chemical intermediates for the production of antioxidants, pharmaceuticals, agricultural and rubber chemicals, and hence our interest in their facile separation.[19] We discovered that the two title host compounds display marked differences in the extent of their selectivities for these guests, despite their structural similarities, and explore this phenomenon using single crystal X-ray diffraction experiments and thermal analyses, and report on these findings here.

2. Results and discussion

Hosts **TETROL** and **DMT** were readily prepared in moderate yield according to published procedures.[10,11]

2.1. Single solvent complex formation

TETROL and **DMT** were individually assessed for their host abilities in the presence of each of the toluidine isomers. Therefore, each host (approximately 0.1 g) was dissolved in an excess of the guest (in the case of ***p*-TOL**, which is a solid at room temperature, ethanol was added as co-solvent to achieve this). The vials were left open to the ambient atmosphere, which facilitated the crystallization process. The so-formed crystals were collected by means of vacuum filtration, washed efficiently with low boiling petroleum ether (40–60 °C) to remove superficial guest solvent, and dried. These solids were analysed by means of ^{1}H NMR spectroscopy, using $CDCl_3$ as the deuterated solvent, to determine if inclusion had occurred. Integration of relevant host and guest resonances provided the host:guest (H:G) ratio in each case, and these are summarized in Table 1.

TETROL favoured the 2:3 H:G ratio when including guest solvents ***m*-TOL** and ***p*-TOL** (Table 1). ***o*-TOL** was not enclathrated in this way. On the other hand, **DMT** included all three of these isomers and consistently with a H:G ratio of 2:1 (In the Supplementary Information, Figs. 1S and 2S show the ^{1}H NMR spectra for **2TET·3*m*-TOL** and **2DMT·*o*-TOL**, respectively, as representative examples).

Table 1
H:G ratios[a] for the single solvent experiments using **TETROL** and **DMT** as hosts, and the toluidine isomers as guests.

Host	Guest	H:G ratio
TETROL	***o*-TOL**	–[b]
TETROL	***m*-TOL**	2:3
TETROL	***p*-TOL**	2:3
DMT	***o*-TOL**	2:1
DMT	***m*-TOL**	2:1
DMT	***p*-TOL**	2:1

[a] Determined using ^{1}H NMR spectroscopy with $CDCl_3$ as the deuterated solvent.
[b] No inclusion occurred.

2.2. Competition experiments

In order to ascertain whether these host compounds display any selective behaviour in the presence of mixed guests, each host material (approximately 0.3 mmol) was dissolved, in vials, in equimolar binary and ternary mixtures of these guests (approximately 5 mmol of each). The vessels were closed and stored at 0 °C so as to maintain the equimolar condition. Once crystallization occurred, the formed solids were treated as in the single solvent experiments. GC-MS was selected as the more appropriate quantitative analytical technique for these complexes owing to the overlap of guest-guest resonance signals in the ^{1}H NMR spectra. CH_2Cl_2 was used as the dissolution solvent in each instance. Table 2 summarizes the data so-obtained, where the preferred guest is shown in bold.

The recrystallization of **TETROL** and **DMT** from the various equimolar guest mixtures afforded mixed complexes in each case, with the exception of the experiment comprising **TETROL** and the equimolar binary guest mixture ***o*-TOL**/***m*-TOL**, where crystallization failed to occur. However, **DMT**, in an equivalent experiment, did indeed furnish crystals, and these contained a significantly larger amount of ***o*-TOL** (72.5%) relative to ***m*-TOL**. When **TETROL** was recrystallized from ***o*-TOL**/***p*-TOL**, the host displayed high selectivity for the *para* isomer, extracting 83.5% of this isomer from the mixture, while **DMT** was somewhat more ambivalent, showing

Table 2
H:G ratios[a] for the equimolar mixed solvent experiments using **TETROL** and **DMT** as hosts, and the toluidine isomers as guests.

Host	***o*-TOL**	***m*-TOL**	***p*-TOL**	Guest ratios (%e.s.d.s)[b]	H:G ratio
TETROL	x	x		–[c]	–[c]
TETROL	x		**x**	16.5:**83.5** (0.3)	2:3
TETROL		x	**x**	29.9:**70.1** (0.4)	2:3
TETROL	x	x	**x**	14.2:27.3:**58.5** (0.1) (0.6) (0.7)	2:3
DMT	**x**	x		**72.5**:27.5 (0.1)	2:1
DMT	x		**x**	46.7:**53.3** (0.1)	2:1
DMT		x	**x**	28.7:**71.3** 90.8)	2:1
DMT	x	x	**x**	40.1:15.7:**44.2** (0.6) (1.1) (0.4)	2:1

[a] Determined using GC-MS with CH_2Cl_2 as the dissolution solvent.
[b] These experiments were carried out in triplicate, and percentage estimated standard deviations (%e.s.d.s) are provided in parentheses.
[c] Crystals failed to form.

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only a slight preference for ***p*-TOL** (53.3%). Using ***m*-TOL**/***p*-TOL** as the solvent system resulted in very similar data for both hosts, with **TETROL** extracting 70.1% and **DMT** 71.3% ***p*-TOL**. The ternary experiments provided the host selectivity for the three guests and these are in the order ***p*-TOL** (58.5%) > ***m*-TOL** (27.3%) > ***o*-TOL** (14.2%) and ***p*-TOL** (44.2%) > ***o*-TOL** (40.1%) > ***m*-TOL** (15.7%) for **TETROL** and **DMT**, respectively. Hence, while both hosts are selective for the *para* isomer, the extent of this selectivity is markedly different: **TETROL** usually displays significantly higher preferential behaviour than **DMT**. Furthermore, **DMT** favoured ***o*-TOL** relative to ***m*-TOL**, while the opposite was true for **TETROL**.

We subsequently mixed various combinations of two guests in unequal molar amounts, and recrystallized each of the hosts from these binary mixtures. The data from such experiments would provide information on whether the selectivities of these hosts are dependent on the amount of each guest present. In order to achieve this, we analysed, by means of GC-MS, both the crystals that resulted from each experiment (Z) and also the mother liquor from which the crystals had formed (X). A plot of Z against X, therefore, afforded a selectivity profile for each host compound. Note that since **TETROL** failed to furnish crystals from the ***o*-TOL**/***m*-TOL** mixture, the selectivity profile of the host for this solvent mixture could not be determined. Fig. 1a–e display the results. (The linear plot in each figure is hypothetical, and represents the behaviour of the host if it were completely unselective, and has been inserted for ease of comparison with the experimental data.)

When considering the selective behaviour of **TETROL** when recrystallized from ***p*-TOL**/***m*-TOL** and ***p*-TOL**/***o*-TOL** (Fig. 1a and b, respectively), it is clear that the host is significantly more selective for ***p*-TOL** when this guest is mixed in various proportions with the *ortho* isomer than it is when ***p*-TOL** is mixed with the *meta* isomer. The selectivity coefficient, K,[19] was determined to be 1.9 (***p*-TOL**/***m*-TOL**) and 10.0 (***p*-TOL**/***o*-TOL**). **DMT**, on the other hand, displays very similar selectivity for ***p*-TOL** and ***o*-TOL** when these guests are mixed with ***m*-TOL** (Fig. 1c and e) and, unsurprisingly, K was comparable in both experiments (2.62 and 2.58, respectively). An assessment of Fig. 1b and d shows the striking selectivity differences between the two hosts when recrystallized from ***p*-TOL**/***o*-TOL** mixtures: while both hosts are selective for ***p*-TOL**, the extent of the selectivity is significantly different, with **DMT** displaying a very low selectivity for this isomer (K = 1.2, Fig. 1d) compared with **TETROL** (K = 10.0).

We were determined to investigate the reasons for the selectivity differences between the two host materials, and consequently carried out single crystal diffraction experiments on suitable crystals that formed from each of the single solvent complexes.

2.3. Single crystal diffraction experiments

Each of the single solvent complexes of **TETROL** and **DMT** with the respective guests were subjected to single crystal X-ray diffraction experiments. These experiments were conducted at 200 K using a Bruker Kappa Apex II diffractometer with graphite-monochromated Mo Kα radiation (λ = 0.71073 Å). APEXII and SAINT were used for data collection, and cell refinement and data reduction, respectively.[20] SHELXT-2014[21] was used to solve the structures, and refined by least-squares procedures using SHELXL-2017/1;[21] here, SHELXLE[22] served as a graphical interface. All non-hydrogen atoms were refined anisotropically, and these were

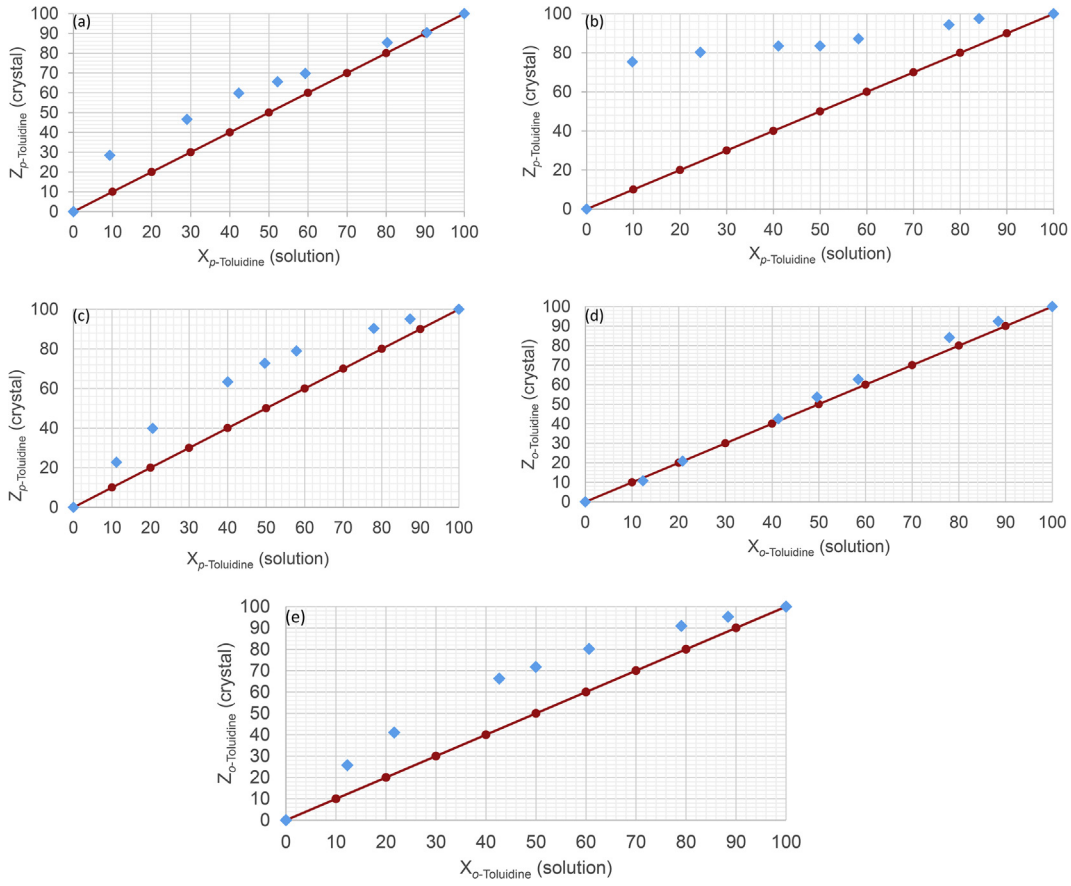

Fig. 1. Selectivity profiles for (a) **TETROL**/***p*-TOL**/***m*-TOL**, (b) **TETROL**/***p*-TOL**/***o*-TOL**, (c) **DMT**/***p*-TOL**/***m*-TOL**, (d) **DMT**/***p*-TOL**/***o*-TOL** and (e) **DMT**/***o*-TOL**/***m*-TOL** experiments.

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placed in idealized geometrical positions in a riding model. Data were corrected for absorption effects using the numerical method implemented in SADABS.[20] The H atoms of the hydroxyl groups of **TETROL** were allowed to rotate with a fixed angle around the C–O bonds to best fit the experimental electron density (HFIX 147 in the SHELX program suite).[21] The crystal data for all complexes were deposited at the Cambridge Crystallographic Data Centre [CCDC 1823424 (**2TET·3*m*-TOL**), 1823425 (**2TET·3*p*-TOL**), 1823803 (**2DMT·*o*-TOL**), 1823804 (**2DMT·*m*-TOL**) and 1823805 (**2DMT·*p*-TOL**)].

Table 3 contains a summary of the relevant crystallographic data obtained for these complexes. The **TETROL**/***m*-TOL** inclusion compound crystallizes in the triclinic crystal system and *P*1 space group, while that containing ***p*-TOL** crystallizes in the orthorhombic crystal system and $P2_12_12_1$ space group. The three **DMT** complexes all experience isostructural host packing (monoclinic, *C*2), and each guest displays symmetry-generated disorder which is well-modelled. Note that the nitrogen-bound hydrogens in the third guest in **2TETROL·3*m*-TOL** and **2TETROL·3*p*-TOL**, as well as the guests in each of the three **DMT** complexes, could not be located owing to the disorder in these guests.

Unit cells for **2TETROL·3*m*-TOL**, **2TETROL·3*p*-TOL** and **2DMT·*p*-TOL** (as representative example for the three DMT complexes due to the likeness of **DMT**'s packing with the toluidine guests) are displayed in Fig. 2a–c, respectively, while Fig. 2d–f are as a result of the removal of the guest molecules from the packing calculation in the Mercury software program in order to visualize the nature of the guest accommodation, whether in channels or isolated cavities.

Both complexes with **TETROL** show that the guests are accommodated within highly constricted channels, while guests in the **DMT** complexes all experience discrete cavity occupation.

In order to determine the reasons for the host selectivity behaviour differences, we analysed the host–guest interactions from these diffraction data, and these are provided in Table 4. Immediately evident from these data is the reason for the high selectivity displayed by **TETROL** for -***p*-TOL**: the number of host–guest interactions experienced in this complex far surpasses those in the complex containing ***m*-TOL**. This is true for π–π, CH–π and the various other short contacts that are possible. Furthermore, both ordered guest molecules in **2TETROL·3*m*-TOL** function as hydrogen bond acceptors with an hydroxyl group of the host molecule [2.722(3) Å, 165° and 2.771(3) Å, 160°, respectively)] while the disordered third guest here does not experience an interaction of this type. The case is similar for the **2TETROL·3*p*-TOL** complex, the interactions to each of the ordered guests measuring 2.731(3) Å, 158° and 2.710(3) Å, 165°; once more, the third guest is not H-bonded in this way. These data suggest that hydrogen bonding is important in these complexes and serves to anchor the guests in one particular orientation, ensuring that these are ordered in the crystal. When hydrogen bonding is absent, as in guest 3 in these structures, the guest is able adopt more than one orientation, thus resulting in the disorder that we observed.

While SCXRD data for the three complexes with **DMT** do not explain the observed host selectivity order for these guests, these data do, however, explain why **TETROL** is significantly more selective than **DMT**. Firstly, the number of host–guest interactions is surprisingly contrasting in complexes with **TETROL** compared with those of **DMT**, with the former experiencing substantially more of these. In fact, **DMT** displays very few interactions indeed with the three guests, and only π–π and one other short contact could be found in each complex. Secondly, **TETROL** alone behaves as a hydrogen bond donor to guests, and **DMT**, whilst having the ability to do so by means of the two hydroxyl functionalities, does not hydrogen bond at all in this way. It is suggested that the increased selectivity of **TETROL** compared with **DMT** is due to the difference

Table 3
Crystallographic data for complexes of **TETROL** and **DMT** with the toluidine isomers.[a]

	2TETROL·3*m*-TOL	**2TETROL·3*p*-TOL**	**2DMT·*o*-TOL**	**2DMT·*m*-TOL**	**2DMT·*p*-TOL**
Chemical formula	$2(C_{28}H_{26}O_4)\cdot 2(C_7H_9N)\cdot(C_7H_7N^b)$	$2(C_{28}H_{26}O_4)\cdot 2(C_7H_9N)\cdot(C_7H_7N^b)$	$C_{30}H_{30}O_4\cdot 0.5C_7H_7N^b$	$C_{30}H_{30}O_4\cdot 0.5C_7H_7N^b$	$C_{30}H_{30}O_4\cdot 0.5C_7H_7N^b$
Formula weight	1172.42	1172.41	1014.21	1014.21	1014.21
Crystal system	Triclinic	Orthorhombic	Monoclinic	Monoclinic	Monoclinic
Space group	*P*1	$P2_12_12_1$	*C*2	*C*2	*C*2
μ (Mo-Kα)/mm^{-1}	0.078	0.078	0.079	0.079	0.079
a/Å	10.7717(4)	17.4913(5)	17.3965(11)	17.4485(12)	17.2804(19)
b/Å	11.8825(5)	18.5146(5)	11.9219(7)	12.0156(8)	12.0944(14)
c/Å	13.4957(6)	19.8236(6)	14.2165(9)	14.1121(10)	14.0931(16)
α/°	86.693(2)	90	90	90	90
β/°	79.059(2)	90	109.803(3)	110.179(2)	110.363(4)
γ/°	71.473(2)	90	90	90	90
V/Å^3	1608.08(12)	6419.8(3)	2774.1(3)	2777.1(3)	2761.3(5)
Z	1	4	2	2	2
D(calc)/g.cm^{-3}	1.211	1.213	1.214	1.213	1.220
F(000)	624	2496	1080	1080	1080
Temp./K	200	200	200	200	200
Restraints	7	21	1	1	1
Nref	14904	15966	5477	6833	6617
Npar	808	790	372	372	350
R1	0.0405	0.0420	0.0318	0.0339	0.0358
w*R*2	0.1087	0.1066	0.0892	0.0929	0.0902
S	1.02	1.02	1.04	1.04	1.06
θ min-max/°	1.8, 28.3	1.6, 28.3	2.1, 28.3	2.1, 28.3	2.1, 28.3
Tot. data	56880	116349	30507	54025	22149
Unique data	14904	15966	5477	6833	6617
Observed data [I > 2.0 sigma(I)]	12943	12034	5040	6525	5913
R_{int}	0.020	0.027	0.020	0.016	0.021
Dffrn measured fraction θ full	1.000	1.000	1.000	0.999	0.998
Min. resd. dens. (e/Å^3)	−0.21	−0.22	−0.15	−0.23	−0.20
Max. resd. Dens. (e/Å^3)	0.28	0.29	0.19	0.21	0.26

[a] **TETROL** did not include ***o*-TOL**.
[b] Nitrogen-bound hydrogen atoms could not be located due to the disorder in these guest molecules.

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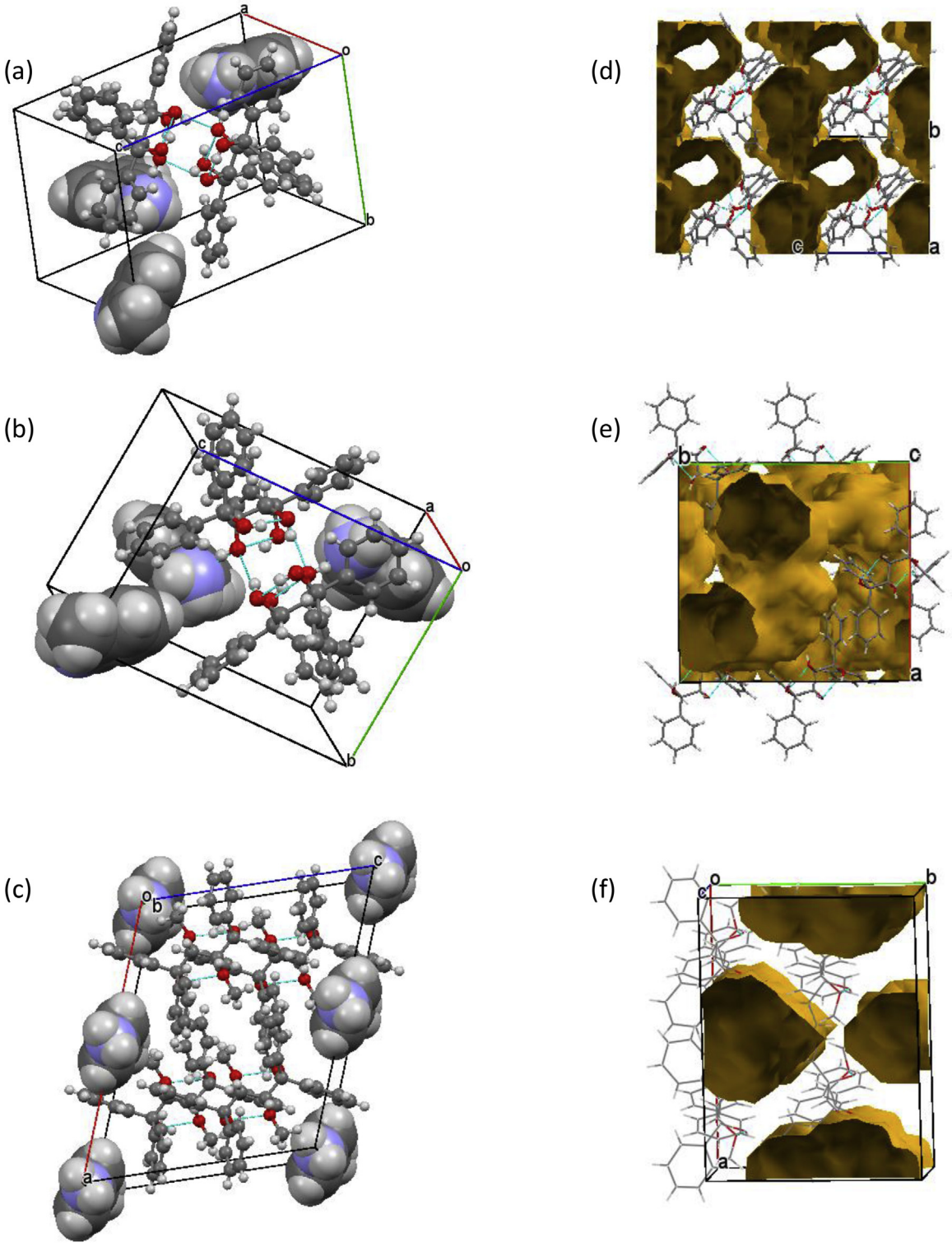

Fig. 2. Unit cells for (a) **2TETROL·3*m*-TOL**, (b) **2TETROL·3*p*-TOL** and (c) **2DMT·*p*-TOL**; calculated voids for (d) **2TETROL·3*m*-TOL**, (e) **2TETROL·3*p*-TOL** and (f) **2DMT·*p*-TOL**.

in the number of host–guest interactions as well as the presence of hydrogen bonding in complexes with the former host and absence of these in the latter.

2.4. Thermal analysis

We analysed the five complexes by means of thermal analyses in order to determine whether these results would explain the observed selectivity orders for the two host materials. Overlaid thermogravimetric (TG, green), differential scanning calorimetric (DSC, brown) and the derivative of the TG (DTG) traces are provided in Fig. 3a–e, which were obtained after heating each of the complexes at 10 °C.min^{-1} from room temperature until approximately 250 °C.

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Table 4
Significant H–G interactions for complexes of **TETROL** and **DMT** with the toluidine isomers.[a]

Non-covalent interaction	**2TETROL·3*m*-TOL**[b] (number of contacts)	**2TETROL·3*p*-TOL**[b] (number of contacts)	**2DMT·*o*-TOL**[c] (number of contacts)	**2DMT·*m*-TOL**[c] (number of contacts)	**2DMT·*p*-TOL**[c] (number of contacts)
π–π	4.7349(17)–5.8891(15) Å (15)	5.959(3)–4.9399(15) Å (25)	5.359(4)–5.891(4) Å (8)	5.033(2)–5.971(2) Å (8)	5.3154(15)–5.8618(15) Å (4)
XH…π	(guest 2)NH…π(host) 2.95(3) Å, 163(3)° (guest 2)NH…π(host) 2.54(6) Å, 138(5)° (guest methyl)CH…π(host) 2.88 Å, 122° (host Ar)CH…π(guest 3) 2.95 Å, 162°	(guest 1)NH…π(host) 2.82(2) Å, 168(2)° (guest 1)NH…π(host) 2.67(3) Å, 130(2)° (guest 2)NH…π(host) 2.79(4) Å, 169(3)° (host Ar)CH…π(guest 3) 2.99 Å, 169° (host Ar)CH…π(guest 3) 2.90 Å, 164° (host Ar)CH…π(guest 3) 2.98 Å, 163° (host Ar)CH…π(guest 3) 2.84 Å, 157° (guest 3 Ar)CH…π(guest 2) 2.93 Å, 141°	None	None	None
Other short contacts	(guest 2 Ar)CH···CC(host Ar) 2.83 Å, 141°	(guest 1)NH…CC(host) 2.81(2) Å, 163(2)° (host Ar)CH…HC(guest 3 methyl) 2.25 Å, 150° (host Ar)CH…CC(guest 3) 2.81 Å, 142° (host Ar)CH···CC(guest 3) 2.80 Å, 137° (guest 3 Ar)CH…CN(guest 2) 2.84 Å, 148°	(host Ar)CH···N(guest) 2.52 Å, 177°	(guest Ar)CH···CH(host Ar) 2.88 Å, 156°	(host Ar)CH···CC(guest Ar) 2.89 Å, 144°
H-bonding	(host)OH···N(guest 1) 2.722(3) Å, 165° (host)OH···N(guest 2) 2.771(3) Å, 160°	(host)OH…N(guest 2) 2.731(3) Å, 158° (host)OH···N(guest 1) 2.710(3) Å, 165°	None	None	None

[a] H = host, G = guest.
[b] Guests are labelled "guest 1", "guest 2" and "guest 3" for the three guests in the unit cell; guest 3 showed disorder.
[c] Nitrogen-bound hydrogen atoms could not be located due to the disorder in these guest molecules.

Relevant thermal data are summarized in Table 5, where T_b is the boiling point of pure guest and T_{on} the temperature for the onset of the guest release process (estimated from the DTG trace). The function $T_{on}-T_b$ is a measure of the relative thermal stabilities of complexes,[23] and is more valid when the host packing is isostructural. The less negative the value obtained, the more stable the complex is. This function was therefore disregarded for the two **TETROL** complexes (since these were not isostructural), and only considered for the **DMT** inclusion compounds.

All of the complexes experience a guest release process that is concomitant with the host melt. Expected mass losses for each of these complexes were in close agreement with the mass losses obtained experimentally. Furthermore, the thermal traces of the **TETROL** complexes are more convoluted than those of the **DMT** inclusion compounds. This is expected since the three guests in **2TETROL·3*m*-TOL** and **2TETROL·3*p*-TOL** do not all experience hydrogen bonding with the host and will, therefore, in all likelihood, be released at different temperatures, resulting in traces that are more complex. On the other hand, the guests in each of the complexes with **DMT** experience very similar (and few) interactions with the host, none of which are hydrogen bonding, and uncomplicated traces are the result. Using T_{on} as an indicator of the relative thermal stabilities of the **TETROL** complexes, an order of ***p*-TOL** (73.8 °C) > ***m*-TOL** (56.4 °C) is obtained, while $T_{on}-T_b$ calculations afford a ***p*-TOL** (−106.7 °C) > ***o*-TOL** (−107.1 °C) > ***m*-TOL** (−107.5 °C) order. Both of these correlate exactly and therefore explain the host selectivity for these complexes.

3. Conclusions

In this work, the host abilities of two similar compounds, **TETROL** and **DMT**, were compared when crystallized in the presence of the toluidine isomers. **TETROL** preferred a 2:3 H:G ratio and only included the *meta*- and *para*- isomers, while **DMT** formed complexes with all three guests with a 2:1 ratio. Competition experiments in which these hosts were recrystallized from mixed guests showed **TETROL** to be significantly more selective than **DMT**, and analyses of data from single crystal diffraction experiments provided the reason: complexes with **TETROL** experienced a substantial number of various intermolecular host–guest interactions, while it was striking that **DMT** retained the guests by means of only π–π interactions and a single other short contact. These observations, together with the fact that **TETROL** also behaves as a hydrogen bond donor towards these guests while **DMT** does not, account for these selectivity differences. Furthermore, thermal analyses confirmed the selectivity orders for both hosts.

4. Experimental

4.1. General methods

Melting points (uncorrected) were recorded on a Stuart SMP10 melting point apparatus. ^{1}H NMR spectra were obtained using a 400 MHz Bruker Avance Ultrashield Plus 400 Spectrometer. Thermal experiments were carried out on a TA SDT Q600 Module system and analysed using TA Universal Analysis 2000 data analysis

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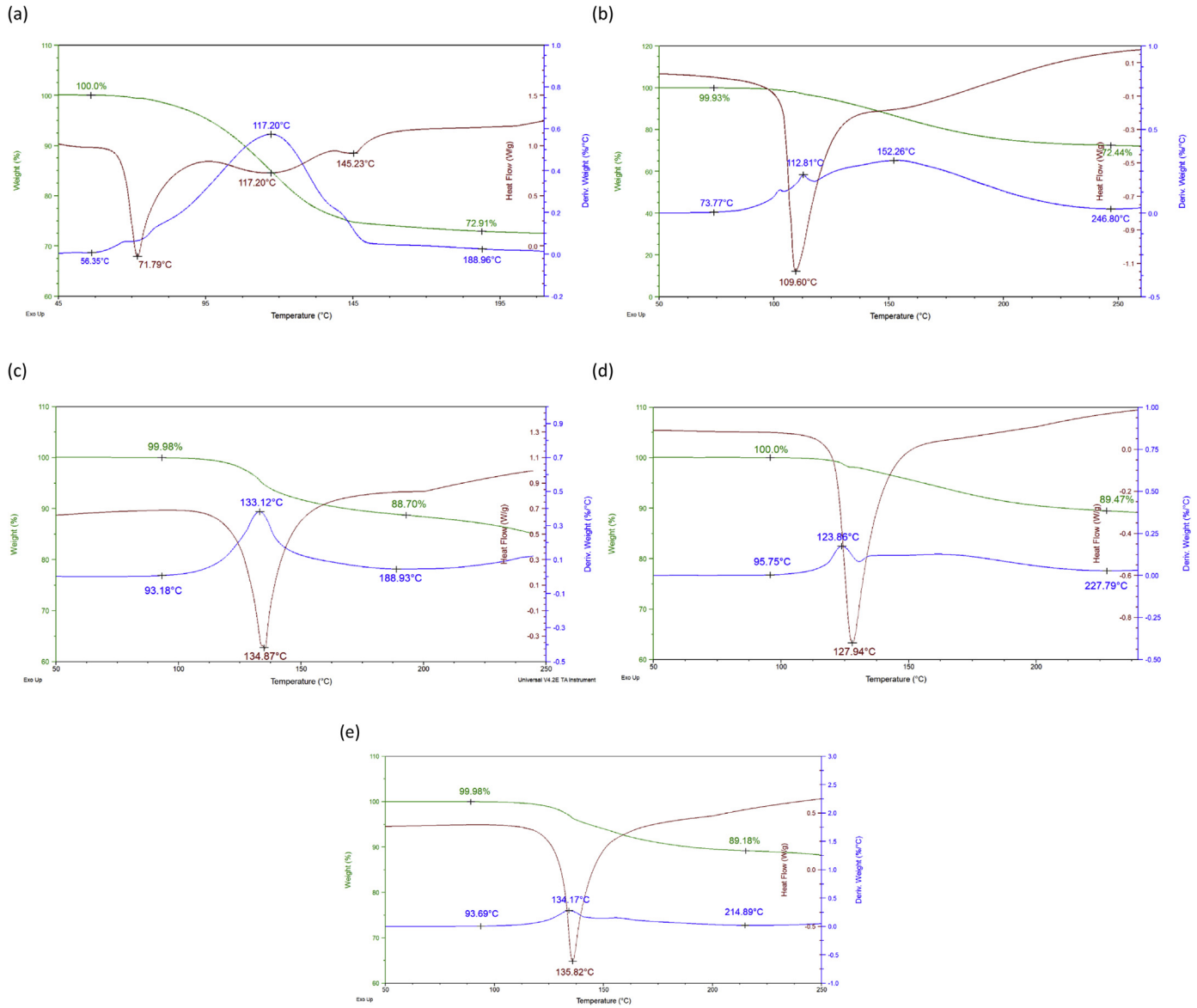

Fig. 3. Overlaid TG (green), DSC (brown) and DTG (blue) traces for (a) **2TETROL·3*m*-TOL**, (b) **2TETROL·3*p*-TOL**, (c) **2DMT·*o*-TOL**, (d) **2DMT·*m*-TOL** and (e) **2DMT·*p*-TOL**.

Table 5
Relevant thermal data from the TG, DSC and DTG traces.

H:G complex	T_b/°C	T_{on}/°C	$T_{on}-T_b$/°C	Mass loss observed/%	Mass loss expected/%
2TETROL·3*m*-TOL	203.3	56.4	N/A	27.1	27.4
2TETROL·3*p*-TOL	200.4	73.8	N/A	27.5	27.4
2DMT·*o*-TOL	200.3	93.2	−107.1	11.3	10.5
2DMT·*m*-TOL	203.3	95.8	−107.5	10.5	10.5
2DMT·*p*-TOL	200.4	93.7	−106.7	10.8	10.5

software. Samples were placed in open platinum pans and an empty platinum pan functioned as a reference. High purity nitrogen gas was used as purge gas here. GC-MS experiments were carried out on an Agilent 7890A gas chromatograph fitted with an Agilent 5975C VL mass spectrometer, and the column was a Cyclosil-B column (30 m). From an initial temperature of 60 °C, a heating rate of 2.5 °C.min^{-1} was employed up to 130 °C, with a final hold time of 1 min.

4.2. Synthesis of *TETROL* and *DMT*

These host materials were synthesized in our laboratory according to previous reports.[10,11]

4.2.1. *TETROL*[10]

Bromobenzene (22.99 g, 146.5 mmol), magnesium turnings

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(3.94 g, 162.0 mmol) and (+)-diethyl L-tartrate (5.00 g, 24.3 mmol), in a standard Grignard reaction, afforded a gum which recrystallized from CH_2Cl_2/hexane/MeOH to afford **TETROL** as a white solid (4.68 g, 10.9 mmol, 45%), mp 147–149 °C (lit.,[24], mp 150–151 °C); $[\alpha]_D^{23}$ +166° (c = 9.32, CH_2Cl_2) {lit.,[24], $[\alpha]_D^{25}$ +154° (c = 1.2, $CHCl_3$)}; ν_{max}(solid)/cm^{-1} 3440 (br, OH), 3294 (br, OH), 3057 (Ar), 3033 (Ar), 1598 (Ar) and 1494 (Ar); δ_H($CDCl_3$) 3.86 (2H, d, 2CO<u>H</u>), 4.44 (2H, d, 2<u>H</u>COH), 4.72 (2H, s, 2CPh$_2$O<u>H</u>) and 7.2–7.4 (20H, m, Ar); δ_C($CDCl_3$) 72.1 (H<u>C</u>OH), 81.7 (<u>C</u>Ph$_2$OH), 125.0 (Ar), 126.1 (Ar), 127.2 (Ar), 127.3 (Ar), 128.10 (Ar), 128.4 (Ar), 128.6 (Ar), 130.1 (Ar), 143.9 (quaternary Ar) and 144.2 (quaternary Ar).

4.2.2. ***DMT***[11]

Sodium hydride (6.0125 g, 55–65% suspension in mineral oil), **TETROL** (5.48 g, 12.8 mmol) and methyl iodide (3.65 g, 25.9 mmol) yielded **DMT** (3.76 g, 8.27 mmol, 65%) as a white solid, mp 124–126 °C (lit.,[25], mp 125–126 °C); $[\alpha]_D^{23}$ −154.5° (*c*. 0.27, CH_2Cl_2) {lit.,[25], $[\alpha]_D$ −153° (*c*. 0.8, $CHCl_3$)}; ν_{max}(solid)/cm^{-1} 3576-3271 (br, OH), 3025 (Ar), 2836 (O-CH_3), and 1567 (Ar); δ_H($CDCl_3$)/ppm 2.60 (6H, s, 2OC<u>H</u>$_3$), 4.46 (2H, s, 2<u>H</u>COCH$_3$), 4.87 (2H, s, 2CPh$_2$O<u>H</u> [disappears upon addition of D_2O]), 7.17 (2H, m, Ar), 7.26 (4H, m, Ar), 7.32 (2H, m, Ar), 7.46 (4H, m, Ar) and 7.63 (8H, m, *ortho*-Ar); δ_C($CDCl_3$)/ppm 61.0 (O<u>C</u>H$_3$), 80.1 (<u>C</u>Ph$_2$OH), 85.3 (H<u>C</u>OCH$_3$), 125.9 (Ar), 126.1 (Ar), 126.8 (Ar), 127.2 (Ar), 128.0 (Ar), 128.5 (Ar), 144.9 (quaternary Ar) and 145.6 (quaternary Ar).

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.tet.2018.04.039.

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