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PAPER

Some cyclization reactions of 1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one: preparation and computational analysis of non symmetrical zwitterionic biscyanines†

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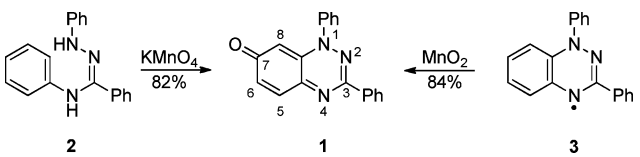
Regioselective nucleophilic addition of bisnucleophiles 1,2-benzenediamine, 2-amino-benzenethiol, and *N*-phenyl-1,2-benzenediamine to 1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**1**) at C6 followed by intramolecular cyclocondensation at the C7 carbonyl afforded highly coloured tetracenes 1,3-diphenyl-1,6-dihydro-[1,2,4]triazino[5,6-*b*]phenazin-4-ium 4-methylbenzenesulfonate (**12**), 1,3-diphenyl-1*H*-[1,2,4]triazino[6,5-*b*]phenothiazine (**14**) and 1,3,11-triphenyl-1,6-dihydro-[1,2,4]-triazino[5,6-*b*]phenazin-11-ium 4-methylbenzenesulfonate (**15**), respectively. Neutralization of the latter with alkali gave the free base 1,3,11-triphenyl-1*H*-[1,2,4]triazino[5,6-*b*]phenazin-11-ium-6-ide (**16**). Furthermore, the benzotriazinone **1** reacts with dimethyl malonate to give 6-(methoxycarbonyl)-7-oxo-1,3-diphenyl-7*H*-benzofuro[5,6-*e*][1,2,4]triazin-1-ium-4-ide (**17**) in 74% yield, while with S_4N_4 [5,6-*c*]-thiadiazolo-7-oxo-1,3-diphenyl-1,2,4-benzotriazine (**22**) was formed in 15% yield. The free bases **16** and **17** display negative solvatochromism, which supports charge separated ground states similar to those of zwitterionic biscyanines, and DFT calculations at the UB3LYP/6-31G(d) level afford ΔE_{ST} values of −13.6 and −18.7 kcal mol^{-1}, respectively that strongly favour the singlet ground state. All ring systems described are new and fully characterized.

1. Introduction

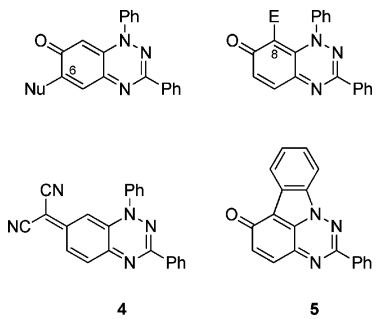
1,3-Diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**1**) is a potentially useful heterocyclic scaffold that is highly coloured (λ_{max} 544 nm), and supports a quinonimine moiety. It was originally prepared in low yield (1–5%) by Neugebauer *et al.*,[1] preventing an in depth study of its potentially rich chemistry. However, by treating amidrazone **2** with $KMnO_4$,[2] or benzotriazinyl radical **3** with MnO_2,[3] the benzotriazinone **1** can be prepared in high yields of 82 and 84%, respectively (Scheme 1).



2 **1** **3**

Scheme 1

Some chemistry of the benzotriazinone **1** has recently been reported:[4,5] benzotriazinone **1** undergoes nucleophilic addition regioselectively at C6, and electrophilic substitution regio-selectively at the C8 position,[4] however, direct condensations on the carbonyl at C7 using primary amines or active methylenes failed. Nevertheless, the ylidenemalononitrile **4** could be prepared in low yield using either tetracyanoethene (TCNE) or tetracyanoethylene oxide (TCNEO).[4] Furthermore, oxidative and non-oxidative silver-mediated palladium catalysed cyclizations at C8 afford the triazafluoranthenone **5**[5] that is structurally similar to the canthinone alkaloids[6,7] (Scheme 2).



4 **5**

Scheme 2

Tentatively, the failure to perform condensation chemistry at the C7 carbonyl was attributed to the strong contribution of a zwitterionic resonance form (Scheme 3).[4]

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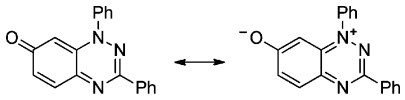
† Electronic supplementary information (ESI) available: ^{1}H and ^{13}C NMR spectra for all new compounds and computational parameters for compounds **16–18**. See DOI: 10.1039/c1ob06622f



1 λ_{max} (DCM) 544 nm (log ε 3.82)

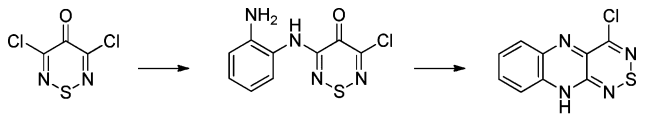
Scheme 3

In this paper we report a regioselective nucleophilic addition of bisnucleophiles at C6 and their subsequent intramolecular cyclocondensation at C7 to afford new fused heterocycles, two of which support zwitterionic motifs. Furthermore, we demonstrate a successful cycloaddition reaction across the C5–C6 double bond.

2. Results and discussion

Reactions with primary anilines

Intermolecular condensations of anilines or active methylenes with benzotriazinone **1** failed to give the desired C7 condensation products.[4] Interestingly we had previously encountered similar difficulties in performing intermolecular condensation reactions with 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **6**[8] but found that reacting the thiadiazinone with bisnucleophiles like 1,2-benzenediamine (*ortho*-phenylenediamine) afforded the monochloro-monoamino-thiadiazinone **7** which readily underwent intramolecular cyclocondensation to give the deep purple coloured quinazoline **8** (Scheme 4).[9] In light of benzotriazinone's regioselective nucleophilic addition at C6[4] a similar strategy could also lead to intramolecular condensations at the benzotriazinone's C7 carbonyl.

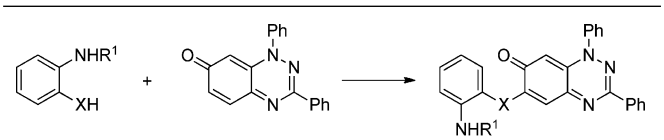


6 **7** **8**

Scheme 4

Ethanol solutions of benzotriazinone **1** were treated with a range of bisnucleophiles (1,2-benzenediamine, *N*-phenylbenzene-1,2-diamine and 2-aminobenzenethiol) and *N*-ethyl-*N*-isopropyl-propan-2-amine (Hünig's base) (1.1 equiv.) and heated to reflux. In the first three cases the expected C6 substituted benzotriazinones **9–11** were obtained as highly coloured compounds.The reaction of 1,2-benzenediamine gave the orange coloured 6-(2-amino-phenylamino)-1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**9**) (λ_{max} 431 nm) in 75% yield (Table 1, entry 1),

Table 1 Reaction of benzotriazinone **1** with bisnucleophiles (2 equiv.) and *i*-Pr_2NEt (1.1 equiv.) in EtOH at *ca.* 78 °C



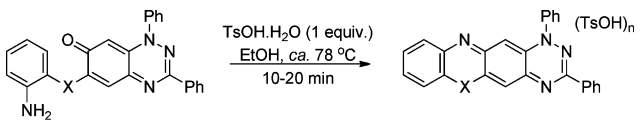
1 **9-11**

Entry	R^1	X	Time (h)	Yield (%)
1	H	NH	25	**9** (75)
2	Ph	NH	48	**10** (51)
3	H	SH	22	**11** (99)

while the red coloured 1,3-diphenyl-6-[2-(phenylamino)phenylamino]-benzo[*e*][1,2,4]triazin-7(1*H*)-one (**10**) (λ_{max} 430 nm) was isolated from the reaction mixture of benzotriazinone **1** and *N*-phenylbenzene-1,2-diamine in a more moderate yield (51%) (Table 1, entry 2). The reaction of benzotriazinone **1** with 2-aminobenzenethiol gave the brown coloured 6-(2-aminothiophenyl)-1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**11**) (λ_{max} 520 nm) in 99% yield (Table 1, entry 3).

Subsequent treatment of substituted benzotriazinones **9–11** with TsOH·H_2O (1 equiv.) in EtOH heated at reflux for 10 or 20 min gave the expected cyclization products either as the tosylates or, when treated with aqueous alkali, as the free bases. In the absence of an alkali work up the reaction of benzotriazinone **9** with TsOH·H_2O gave 1,3-diphenyl-1,6-dihydro-[1,2,4]triazino[5,6-*b*]phenazin-4-ium 4-methylbenzenesulfonate (**12**) that readily precipitated from the reaction mixture on cooling and was isolated by filtration as deep blue needles (λ_{max} 560 nm) in 78% yield. Alkali (10% NaOH) treatment of this reaction mixture gave the free base 1,3-diphenyl-1,6-dihydro-[1,2,4]triazino[5,6-*b*]phenazine (**13**), giving correct elemental analysis, however, ^{1}H and ^{13}C NMR spectroscopy in either $CDCl_3$, DMSO-d_6 or TFA-d_1, failed to give good spectra owing to poor solubility.

Similar treatment of 6-(2-aminothiophenyl)-1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**11**) with TsOH·H_2O (1 equiv.), followed by a basic work-up (10% NaOH) gave 1,3-diphenyl-1*H*-[1,2,4]triazino[6,5-*b*]phenothiazine (**14**) as green needles (λ_{max} 674 nm) in 82% yield (Scheme 5).



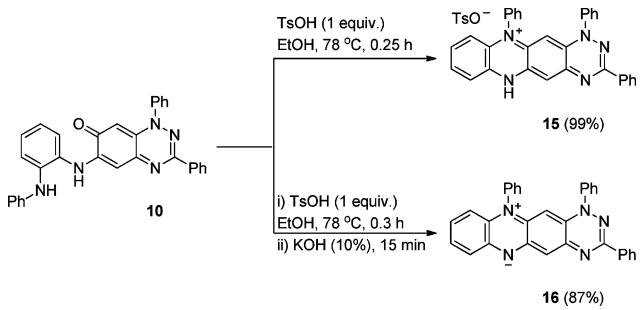
9 (X = NH)
11 (X = S)

12 (X = NH, n = 1), 78%
13 (X = NH, n = 0), 43%
14 (X = S, n = 0), 82%

Scheme 5

On other hand, the reaction of 1,3-diphenyl-6-[2-(phenylamino)phenylamino]benzo[*e*]-[1,2,4]triazin-7(1*H*)-one (**10**) with TsOH·H_2O (1 equiv.) in EtOH heated at *ca.* 78 °C for 10 min gave 1,3,11-triphenyl-1,6-dihydro-[1,2,4]triazino[5,6-*b*]phenazin-11-ium 4-methylbenzenesulfonate (**15**) as blue needles (λ_{max} 620 nm) in 99% yield. Elemental analysis and ^{1}H NMR spectroscopy indicated that this compound co-crystallized with EtOH in a ratio of compound : EtOH (2 : 1). By treating the reaction mixture with a 10% solution of KOH, the free base 1,3,11-triphenyl-1*H*-[1,2,4]triazino[5,6-*b*]phenazin-11-ium-6-ide (**16**) could be isolated as blue needles (λ_{max} 635 nm) in 87% yield (Scheme 6). Interestingly, this compound showed negative solvatochromism[10] (Fig. 1) typical of zwitterionic biscyanines.[11–18]

A number of zwitterionic biscyanines have been reported in the recent literature and all have been symmetrical,[11–18] as such this compound is a rare example of a non symmetrical biscyanine. DFT studies [UB3LYP/6-31G(d)] indicated the molecule strongly preferred the singlet over the possible triplet ground state (ΔE_{ST} –13.6 kcal mol^{-1}). The HOMO and LUMO are similar to those reported for other zwitterionic biscyanines (Fig. 2) and a plot of electrostatic surface potentials (ESP) supports the molecule being charge separated as a biscyanine (Fig. 3).



Scheme 6

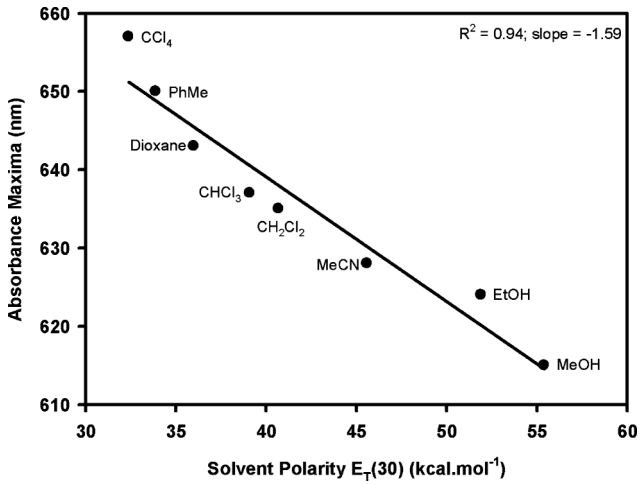


Fig. 1 Correlation between solvent polarity $E_T(30)$[19] and the maximum π–π* absorption of 1,3,11-triphenyl-1*H*-[1,2,4]triazino[5,6-*b*]-phenazin-11-ium-6-ide (**16**) ($n = 8$; $r^2 = 0.94$; slope = –1.59).

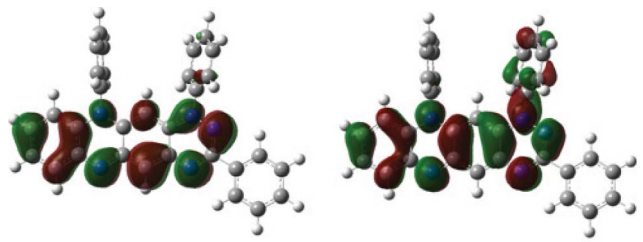


Fig. 2 HOMO (–4.35 eV) and LUMO (–2.25 eV) orbitals of 1,3,11-triphenyl-1*H*-[1,2,4]triazino[5,6-*b*]phenazin-11-ium-6-ide (**16**) [DFT UB3LYP/6-31G(d)].

Furthermore, bond length analysis of the DFT [UB3LYP/6-31G(d)] computed ground state structure showed that the two proposed cyanine fragments were separated by relatively long C–C bonds (C5a–C11a, 146.6 and C4a–C12a, 145.9 pm) typical of zwitterionic biscyanines (Fig. 4).[11–18] Nucleus independent chemical shift (NICS) values of the individual rings that comprise the [1,2,4]triazino[5,6-*b*]phenazine **16** supported the central benzene (ring *C*) being markedly less aromatic than the peripheral arene [NICS (1) (ring *A*) –8.3 *vs.* NICS (1) (ring *C*) –3.5] (Table 2).

However, since negative NICS (1) values are indicative of aromaticity we also calculated the harmonic oscillator model of

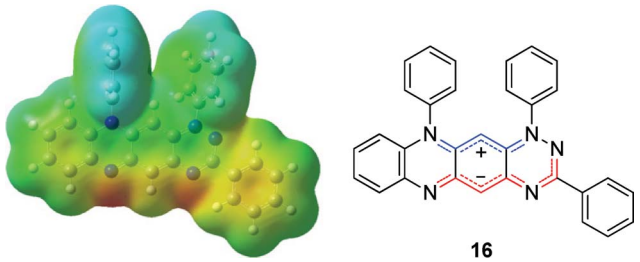


Fig. 3 The electrostatic potential (ESP) mapped on the electron density surface of 1,3,11-triphenyl-1*H*-[1,2,4]triazino[5,6-*b*]phenazin-11-ium-6-ide (**16**) [DFT UB3LYP/6-31G(d)].

Table 2 NICS (0) and NICS (1) values for rings *A*, *B*, *C* and *D* calculated at the B3LYP/6-31G* level for the singlet ground state of the [1,2,4]triazino[5,6-*b*]phenazine **16**

	A	*B*	*C*	*D*
NICS (0)	–7.1	4.8	–0.8	8.7
NICS (1)	–8.3	0.3	–3.5	3.4

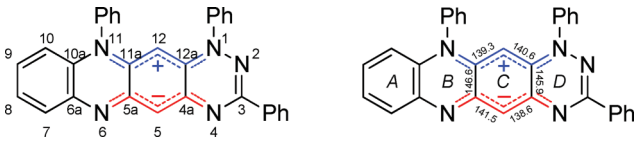


Fig. 4 Compound numbering and selected bond lengths (pm).

aromaticity (HOMA)[20] value for ring *C* (HOMA = 0.47) that is based only on geometric parameters and indicated a low level π-orbital overlap within ring *C* as expected for a zwitterion biscyanine. HOMA is defined as a normalized sum of squared deviations of bond lengths from the optimal value assumed for a fully aromatic system and a fully aromatic system has a HOMA = 1 and a non-aromatic HOMA = 0.

The UV–vis spectrum of monoprotonated 1,3,11-triphenyl-1,6-dihydro-[1,2,4]triazino[5,6-*b*]phenazin-11-ium 4-methylbenzenesulfonate (**15**) (H^+/EtOH, λ_{max} 613 nm) showed a blue shift of the low energy π–π* transitions (~10 nm) when compared to the free base 1,3,11-triphenyl-1*H*-[1,2,4]triazino[5,6-*b*]phenazin-11-ium-6-ide (**16**) (EtOH, λ_{max} 624 nm) (Fig. 5). Similar blue shifts have been observed on mono and bis protonation of zwitterionic quinoxalino[2,3-*b*]phenazines[11,12] and we found that careful addition of (37%) HCl to an EtOH solution of the free base **16** gave the monoprotonated species, which showed a very similar UV–vis spectra (H^+/EtOH, λ_{max} 613 nm) to the *p*-toluenesulfonate salt **15**. Addition of an excess (69–72%) perchloric acid gave no bisprotonation since the same UV–vis spectrum was recorded [H^+/EtOH, λ_{max} 613 nm). The failure to bisprotonate in perchloric acid differed from that of the quinoxalino[2,3-*b*]phenazines,[11,12] indicating that the triazino system was by comparison less basic.

Reactions with active methylenes

Our earlier work[4] attempts to condense malononitrile with the benzotriazinone **1** led to complex highly coloured reaction mixtures, from which no stable product could be isolated. Similar complex reaction mixtures were obtained with another active methylene ethyl 2-cyanoacetate, however, the reaction of benzotriazinone **1** with dimethyl malonate (1.04 equiv.) in the presence of Hünig's

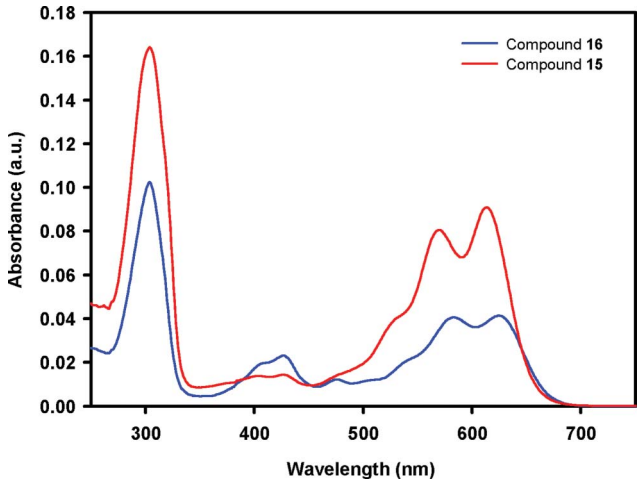
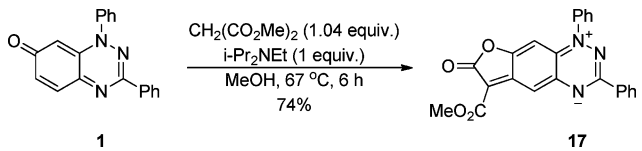


Fig. 5 A comparison of the absorption spectra of the free base 1,3,11-triphenyl-1*H*-[1,2,4]triazino[5,6-*b*]phenazin-11-ium-6-ide (**16**) (λ_{max} 624 nm) and the monoprotonated 1,3,11-triphenyl-1,6-dihydro-[1,2,4]triazino[5,6-*b*]phenazin-11-ium 4-methylbenzenesulfonate (**15**) (λ_{max} 613 nm) in ethanol.

base (1 equiv.) gave 6-(methoxycarbonyl)-7-oxo-1,3-diphenyl-7*H*-benzofuro[5,6-*e*][1,2,4]triazin-1-ium-4-ide (**17**) in 74% yield (Scheme 7).



Scheme 7

6-(Methoxycarbonyl)-7-oxo-1,3-diphenyl-7*H*-benzofuro[5,6-*e*][1,2,4]triazin-1-ium-4-ide (**17**) is deep blue green in solution (λ_{max} 629 nm) suggesting a high degree of conjugation and displayed negative solvatochromism[10] typical of a charge separated ground state (Fig. 6).[19] The compound crystallized as green needles and

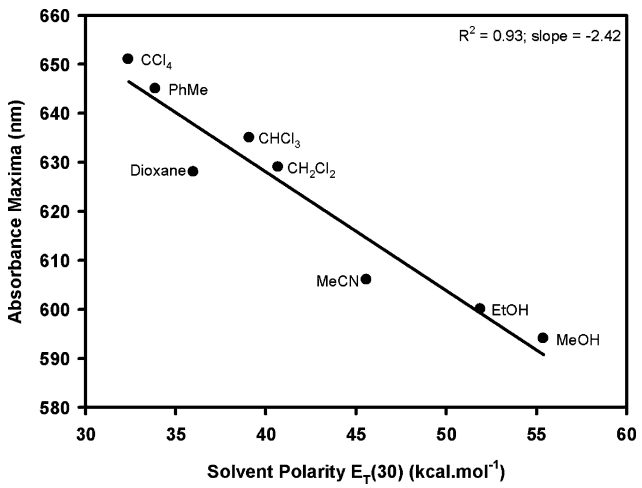


Fig. 6 Correlation between solvent polarity $E_T(30)$[19] and the maximium π–π* absorption of 6-(methoxycarbonyl)-7-oxo-1,3-diphenyl-7*H*-benzofuro[5,6-*e*][1,2,4]triazin-1-ium-4-ide (**17**) ($n = 8$; $r^2 = 0.93$; slope = –2.42).

gave a correct elemental analysis for the formula $C_{23}H_{15}N_3O_4$, which supported a molecular parent ion of m/z 397 Da (100%) from EI mass spectrometry. FTIR spectroscopy indicated the presence of a methyl ester group with a moderately strong carbonyl stretch at ν(C=O) 1761 cm^{-1} and this was also supported by ^{1}H and ^{13}C NMR spectroscopy which showed the presence of a single methoxy group at δ_H 3.92 ppm and δ_C 51.7 ppm. Furthermore, NMR spectroscopy indicated the absence of the H6 benzotriazinone hydrogen and the presence of at least 10 quaternary *C* signals. The data was in agreement with the proposed fused furanone structure.

As such this compound was potentially an additional rare example of a non symmetrical biscyanine. DFT studies [UB3LYP/6-31G(d)] indicated the molecule strongly preferred the singlet over the possible triplet ground state (ΔE_{ST} –18.7 kcal mol^{-1}). The HOMO and LUMO are similar to those reported for other zwitterionic biscyanines (Fig. 7), however, the plot of electrostatic surface potential (ESP) (Fig. 8) suggests considerable positive charge is located at the triazine and that considerable negative charge is located near the furanone.

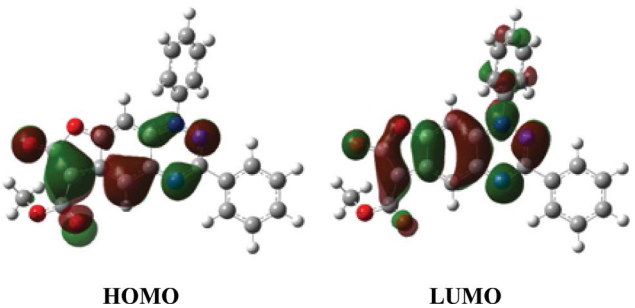


Fig. 7 HOMO (–6.61 eV) and LUMO (–3.36 eV) orbitals of 6-(methoxycarbonyl)-7-oxo-1,3-diphenyl-7*H*-benzofuro[5,6-*e*][1,2,4]triazin-1-ium-4-ide (**17**) [DFT UB3LYP/6-31G(d)].

Fig. 8 The electrostatic surface potential (ESP) mapped on the electron density surface of 6-(methoxycarbonyl)-7-oxo-1,3-diphenyl-7*H*-benzofuro[5,6-*e*][1,2,4]triazin-1-ium-4-ide (**17**) [DFT UB3LYP/6-31G(d)].

In light of the ESP data, the zwitterionic biscyanine motif may not account fully for the structure of this zwitterion. An analysis of the bond lengths and NICS values of the DFT [UB3LYP/6-31G(d)] computed ground state structure showed somewhat

Table 3 NICS (0) and NICS (1) values for rings *A*, *B*, and *C* calculated at the B3LYP/6-31G* level for the singlet ground state of the benzofuro[5,6-*e*][1,2,4]triazin-7(4*H*)-one **17**

	A	*B*	*C*
NICS (0)	−5.2	−6.1	−3.3
NICS (1)	−5.0	−8.0	−6.7

conflicting information: the two C–C bonds that separated the possible cyanine fragments were separated by relatively long C–C bonds (C5a–C8a, 145.4 and C4a–C9a, 147.0 pm) typical of zwitterionic biscyanines.[11–18] However, NICS values of the individual rings that comprise the tricycle supported the central benzene (ring *B*) being markedly aromatic [NICS (1) (ring *B*) –8.0] and in contrast to the [1,2,4]triazino[5,6-*b*]phenazine **16** which had a non-aromatic triazine ring [Fig. 4, Table 2, NICS (1) (ring *D*) +3.4] the NICS (1) value of the triazine ring of the benzofuro[5,6-*e*][1,2,4]triazin-7(4*H*)-one **17** was clearly of opposite sign and mildly aromatic [NICS (1) (ring *C*) –6.7] (Fig. 9, Table 3).

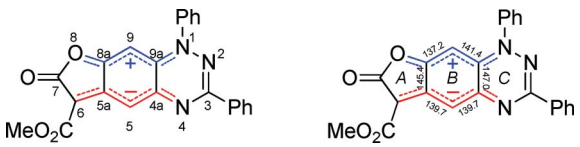
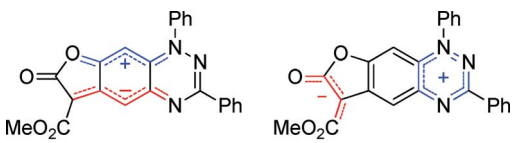


Fig. 9 Compound numbering and selected bond lengths (pm).

As before, we calculated the HOMA[20] value for the central arene (HOMA, ring *B* = 0.48) which was similar to that determined for the equivalent central arene in the [1,2,4]triazino[5,6-*b*]phenazine **16** (HOMA, ring *C* = 0.47) and supported a low level π-orbital overlap within ring *C* as expected for a zwitterion biscyanine. In light of this we propose that the benzofuro[5,6-*e*][1,2,4]triazin-7(4*H*)-one **17** is probably best represented by the biscyanine motif but that there may very well be a significant contribution of resonance structure **17a** (Scheme 8).



Scheme 8

As a final consideration of the nature of the charge separation in compounds **17** we calculated and compared the dipoles (magnitude and vector) for both zwitterions **16** and **17** from the computational structures (Fig. 10).

Perfectly symmetrical zwitterionic biscyanines such as the 5,7-diphenylquinoxalino[2,3-*b*]phenazine **18**[11,12] are expected to have a dipole moment that lines up with the *y*-axis (Fig. 10), and contributions of non-biscyanine charge separated resonance forms such as that depicted in structure **17a** should lead to the dipole moment deviating from the *y*-axis. As can be seen, the calculated dipole moments of both structures **16** and **17** (Fig. 10) deviate from the *y*-axis, the former showing only a minor deviation, and the latter showing a considerable deviation. This adds further support for there being a reasonable

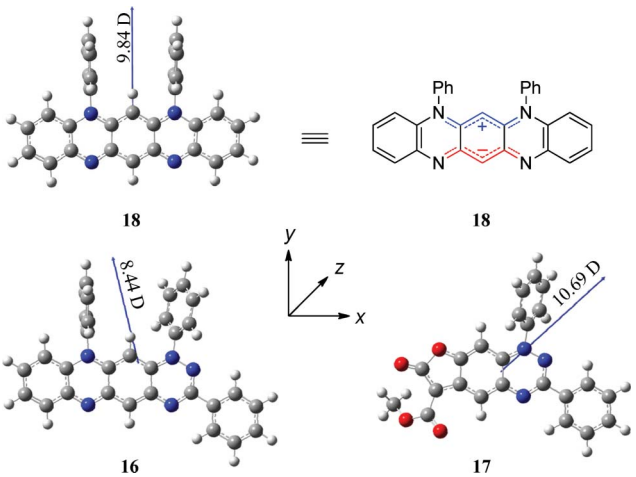


Fig. 10 Dipole moments of 5,7-diphenylquinoxalino[2,3-*b*]phenazine **18**, the [1,2,4]triazino[5,6-*b*]phenazine **16** and the benzofuro [5,6-*e*][1,2,4]triazin-7(4*H*)-one **17** expressed as vectors orientated to an imaginary *y*-axis to enable direct comparison. Charges are fitted to the ESP calculated at the B3LYP/6-31G(d) level and constrained to reproduce the dipole moment.[21,22]

contribution of a charge separated non-biscyanine resonance form in compound **17** (*cf.* structure **17a**) and only a minor one in compound **16**, in line with the calculated electrostatic surface potentials (Fig. 3 and 8).

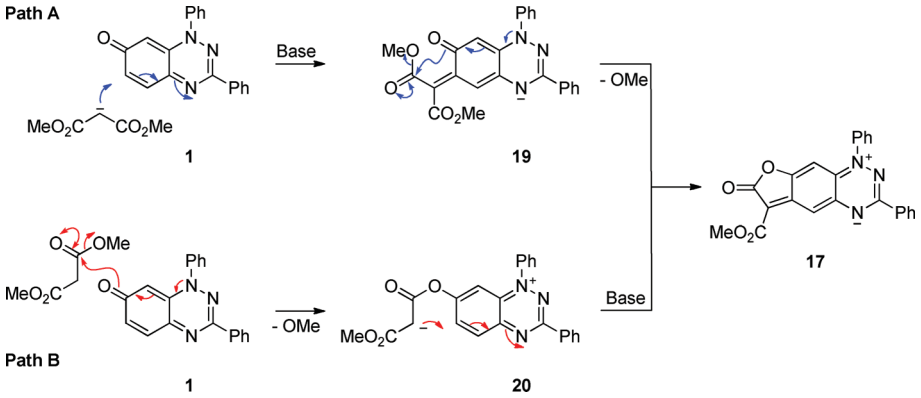
Interestingly, the reaction between dimethyl malonate and the benzotriazinone **1** to give the benzofuro[5,6-*e*][1,2,4]triazin-7(4*H*)-one **17** could occur *via* two different pathways: (Path A) the dimethyl malonate could regioselectively add to the benzotriazinone at C6 to give intermediate **19** and subsequent intramolecular cyclization could occur *via* the benzotriazinone carbonyl, which was expected to be strongly nucleophilic owing to the strong contribution of the benzotriazinone's zwitterionic resonance forms; or (Path B) the reverse could occur, with the dimethyl malonate reacting first with the carbonyl to give intermediate **20** followed by an intramolecular cyclization onto the benzotriazinone C6 position (Scheme 9).

At this stage we are unable to differentiate between these two mechanistic possibilities and this cyclization is now under further investigation.

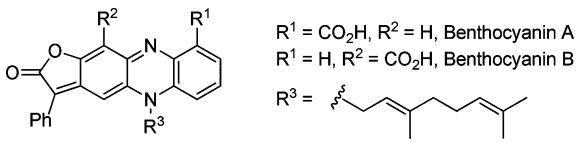
This new fused heterocycle has structural similarities with benthocyanins **21** (Scheme 10) that act as inhibitors of lipid peroxidation in rat microsomes[23] and also showed inhibitory effects on rat erythrocyte hemolysis;[24] as such the benzofurotriazine **17** and related compounds could also show promising biological properties.

Reaction of benzotriazinone 1 with S_4N_4

To check if the double bond between C5 and C6 on the benzotriazinone **1** was susceptible to cycloaddition reactions, benzotriazinone **1** was reacted with various enophiles: the reaction with phenyl azide gave only complex mixtures, while *N*,*N*′-bis(trimethylsilyl)sulfur diimide in DMF at *ca.* 100 °C for 12 h gave only 6-aminobenzotriazinone and unreacted starting material (by TLC). Fortunately, the reaction of benzotriazinone **1** with S_4N_4 (5 equiv.) in DMF at reflux 1 h gave the cyclized [5,6-*c*]thiadiazolo-7-oxo-1,3-diphenyl-1,2,4-benzotriazine (**22**) (15%) together with



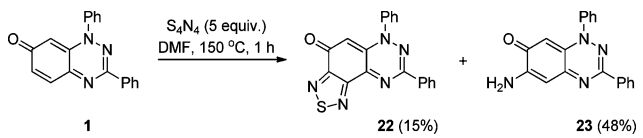
Scheme 9



21

Scheme 10

6-amino-1,2,4-benzotriazinone **23** in 48% yield (Scheme 11). The alternative use of PhCl or xylene as solvents gave very complex reactions, while with PhMe only starting material was recovered from the reaction.



Scheme 11

Compound **22** was brown in solution (λ_{max} 541 nm), tentatively indicating the extensive conjugation of the starting quinonimine had been maintained, and was isolated as brown needles that gave a correct elemental analysis for the formula $C_{19}H_{11}N_5OS$, which supported a molecular parent ion of m/z 357 Da (47%) from EI mass spectrometry. ^{1}H and ^{13}C NMR spectroscopy indicated the absence of the H5 and H6 benzotriazinone hydrogens and the replacement of two aromatic *C*H for two quaternary *C* assignments supporting functionalization at the C5 and C6 carbon positions. The data was in agreement with the proposed fused 1,2,5-thiadiazole structure.

The mechanism of the reaction of S_4N_4 with activated double and triple bonds is based on the reagent's ability to cyclo-add and subsequently fragment to give thermodynamically stable heteroarenes such as 1,2,5-thiadiazoles.[25,26] Rees and Daley[27,28] have conducted extensive studies on these reactions. It is known[29] that in the reactions with S_4N_4, elemental sulfur and ammonia are nearly always formed as side products and the presence of the latter could explain the formation of the 6-aminobenzotriazinone **23**, which can be prepared directly from ammonia and benzotriazinone **1**.[4]

3. Conclusions

1,3-Diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**1**) reacts with bis-nucleophiles, 1,2-benzenediamine, 2-aminobenzenethiol and *N*-phenyl-1,2-benzenediamine, regioselectively at C6 and these adducts on treatment with $TsOH{\cdot}H_2O$ undergo intramolecular cyclocondensation at the C7 carbonyl to afford highly coloured tetracenes 1,3-diphenyl-1,6-dihydro-[1,2,4]triazino[5,6-*b*]phenazin-4-ium 4-methylbenzenesulfonate (**12**), 1,3-diphenyl-1*H*-[1,2,4]triazino[6,5-*b*]phenothiazine (**14**) and 1,3,11-triphenyl-1,6-dihydro[1,2,4]triazino-[5,6-*b*]phenazin-11-ium 4-methylbenzenesulfonate (**15**), respectively. Neutralization of the latter with alkali gave the free base 1,3,11-triphenyl-1*H*-[1,2,4]triazino[5,6-*b*]phenazin-11-ium-6-ide (**16**). A similar cyclo-condensation reaction occurred between dimethyl malonate and benzotriazinone **1** affording 6-(methoxycarbonyl)-7-oxo-1,3-diphenyl-7*H*-benzofuro[5,6-*e*][1,2,4]triazin-1-ium-4-ide (**17**) in 74% yield. Finally, an intermolecular cycloaddition across the C5–C6 bond of benzotriazinone **1** with S_4N_4 gave [5,6-*c*]thiadiazolo-7-oxo-1,3-diphenyl-1,2,4-benzotriazine (**22**) in 15% yield. The free bases **16** and **17** are zwitterions and DFT calculations at the UB3LYP/6-31G(d) level afford ΔE_{ST} values of –13.6 and –18.7 kcal mol^{-1}, respectively that strongly favour the singlet ground state.

4. Experimental

4.1. Computational procedure

The geometries of the singlet and triplet states of molecules **16**–**18** were fully optimized, and analytical second derivatives were computed using vibrational analysis to confirm each stationary point to be a minimum by yielding zero imaginary frequencies at the UB3LYP/6-31G(d) level of theory. The possibility of internal instability in the singlet wave function was investigated using stability calculations. All the energies were corrected after zero-point energies (ZPE) were scaled by 0.981.[30] All the above computations were performed using the Gaussian 03 suite of programs.[31]

Nucleus independent chemical shifts (NICS) were evaluated by using the gauge invariant atomic orbital[32] (GIAO) approach, at the B3LYP/6-31G* level. The NICS probes (bq's) were placed above the geometric centers of the systems at each ring at distances 0.0 Å

(*i.e.*, at the center of the molecular plane) and 1.0 Å perpendicular to the molecular plane.

HOMA[20] values for an all carbon system were calculated using eqn (1), where 257.7 is the normalization value, n = number of C–C bonds, d_{opt} = the optimized bond length (138.8 pm)[20] and d_i = the computed bond length from DFT calculations performed at the UB3LYP/6-31G(d) level of theory.

$$\mathrm{HOMA} = 1 - 257.7/n \sum_{i}^{n} (d_{opt} - d_i)^2, \quad (1)$$

Dipole moments of [1,2,4]triazino[5,6-*b*]phenazine **16** and benzofuro[5,6-*e*][1,2,4]triazin-7(4*H*)-one **17** and 5,7-diphenylquinoxalino[2,3-*b*]phenazine **18** are expressed as vectors, after ESP calculation on G03 at B3LYP/6-31G(d) level of theory to produce charges fit to the electrostatic potential at points selected according to the Merz-Singh-Kollman scheme[21,22] and constrain them to reproduce the dipole moment [pop = (MK, dipole)]. The dipole moment vectors are visualized using GaussView 5.

4.2. General methods and materials

Solvents: DMF was azeotropically distilled with PhH then distilled under vacuum from anhydrous $MgSO_4$ and stored over 4 Å molecular sieves. Reactions were protected by $CaCl_2$ drying tubes. Decomposition points (decomp.) and mp >250 °C were determined using a TA Instruments DSC Q1000 with samples hermetically sealed in aluminium pans under an argon atmosphere, using heating rates of 5 °C min^{-1}. Anhydrous Na_2SO_4 was used for drying organic extracts and all volatiles were removed under reduced pressure. All reaction mixtures and column eluents were monitored by TLC using commercial glass backed thin layer chromatography (TLC) plates (Kieselgel 60 F_{254}). The plates were observed under UV light at 254 and 365 nm. The technique of dry flash chromatography was used throughout for all non-TLC scale chromatographic separations using silica gel 60 (less than 0.063 mm).[33] Melting points were determined using a hotstage microscope apparatus. Solvents used for recrystallization are indicated after the melting point. Inflections in the UV spectra are identified by the abbreviation "inf". FTIR spectra were recorded using a Ge ATR accessory and strong, medium and weak peaks are represented by s, m and w respectively. ^{1}H NMR spectra were recorded at either 300 or 500 MHz and ^{13}C NMR spectra were recorded at either 75 and 125 MHz, respectively. DEPT 135 or APT NMR studies identified quaternary and tertiary carbons, which are indicated by (s) and (d) notations, respectively. Deuterated solvents were used for homonuclear lock and the signals are referenced to the deuterated solvent peaks. Low resolution (EI) mass spectra were recorded on a GCMS with direct inlet probe.

4.3. Substitution at benzotriazinone C-6 position

4.3.1. 6-(2-Aminophenylamino)-1,3-diphenylbenzo[*e*][1,2,4]-triazin-7(1*H*)-one (9). To a stirred solution of 1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**1**) (214 mg, 0.72 mmol) in EtOH (8 ml), Hünig's base (136 μL, 0.79 mmol) and phenylenediamine (155.5 mg, 1.44 mmol) were added and the reaction mixture was heated at reflux for 25 h. The reaction mixture was then allowed to cool to *ca.* 20 °C and the precipitate was filtered and washed with cold hexane to afford the *title compound* **9** (216.4 mg, 75%) as orange needles, mp 278–282 °C (from PhCl); R_f 0.23 (*t*-BuOMe); (found: C, 74.0, H, 4.6; N, 17.2. $C_{25}H_{19}N_5O$ requires C, 74.1; H, 4.7; N, 17.3%); λ_{max}(DCM)/nm 229 (log ε 3.46), 277 inf (3.52), 300 (3.53), 330 inf (3.28), 431 (3.10); ν_{max}/cm^{-1} 3194m (Ar NH), 1631m, 1568m, 1542s, 1516m, 1489s, 1473m, 1455m, 1448m, 1393m, 1379m, 1313m, 1299m, 1272m, 990m, 766m, 747s; δ_H(300 MHz, TFA-d_1) NH and NH_2 exchanged 8.18 (2H, d, *J* 7.7), 7.77–7.62 (9H, m), 7.57–7.52 (1H, m), 7.45 (2H, dd, *J* 7.5, 7.5), 7.18 (2H, dd, *J* 5.5, 5.1); δ_C(75 MHz; TFA-d_1) 160.9 (*C*=O), 159.4 (s), 152.7 (s), 150.1 (s), 142.2 (s), 138.3 (s), 138.2 (s), 135.1 (d), 134.4 (d), 133.8 (d), 132.8 (d), 131.9 (d), 131.5 (s), 130.8 (d), 130.2 (d), 129.5 (d), 127.1 (s), 127.0 (d), 126.5 (d), 101.8 (d), 100.5 (d); *m*/*z* (EI) 406 (M^++1, 12%), 405 (M^+, 39), 388 (100), 300 (11), 180 (13), 104 (7), 77 (36), 65 (12), 51 (10).

4.3.2. 1,3-Diphenyl-6-[2-(phenylamino)phenylamino]benzo[*e*]-[1,2,4]triazin-7(1*H*)-one (10). To a stirred solution of 1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**1**) (100 mg, 0.33 mmol) in EtOH (4 ml), at *ca.* 20 °C, protected with a $CaCl_2$ drying tube, *N*-phenylbenzene-1,2-diamine (123 mg, 0.67 mmol) and Hünig's base (64.7 μl, 0.37 mmol) were added and the reaction mixture was refluxed for 48 h until no starting material remained (TLC). The reaction mixture was then diluted (DCM, 25 ml) and washed (5% HCl, 25 ml) to remove unreacted amine. The organic layer was separated, dried (Na_2SO_4) and adsorbed onto silica. Chromatography (*t*-BuOMe–DCM–hexane, 1 : 6 : 3) gave the *title compound* **10** (58.8 mg, 51%) as red needles, mp 243–245 °C (from PhH), R_f 0.80 (*t*-BuOMe); (found C, 77.4; H, 4.6; N, 14.4. $C_{31}H_{23}N_5O$ requires C, 77.3; H, 4.8; N, 14.5%); λ_{max}(DCM)/nm 234 (log ε 3.39), 289 (3.62), 345 inf (3.06), 430 (3.22), 465 inf (3.20); ν_{max}/cm^{-1} 3200m (N–H), 3065w (Ar CH), 1589m, 1568m, 1549m, 1541m, 1514m, 1487s, 1456m, 1447m, 1396m, 1377m, 1315m, 1290m, 1277m, 989m, 745m, 714m; δ_H(300 MHz, $CDCl_3$) 8.30 (1H, br s, N*H*), 8.26–8.22 (2H, m), 7.62–7.54 (5H, m), 7.48–7.40 (5H, m), 7.29–7.23 (3H, m), 7.08–7.02 (3H, m), 6.98–6.93 (2H, m), 6.19 (1H, s), 5.94 (1H, br s, N*H*); δ_C(75 MHz, $CDCl_3$) one Ar *C* missing 173.4 (*C*=O), 153.1 (s), 152.6 (s), 150.1 (s), 142.5 (s), 141.8 (s), 138.9 (s), 136.2 (s), 135.2 (s), 130.3 (d), 130.2 (d), 130.1 (d), 129.5 (d), 128.7 (d), 127.7 (d), 127.1 (d), 126.1 (d), 125.4 (d), 122.0 (d), 121.5 (d), 119.3 (d), 118.1 (d), 98.7 (d), 94.6 (d); *m*/*z* (EI) 482 (M^++1, 6%), 481 (M^+, 15), 464 (100), 389 (9), 207 (9), 180 (7), 167 (6), 77 (25), 51 (6).

4.3.3. 6-(2-Aminothiophenyl)-1,3-diphenylbenzo[*e*][1,2,4]-triazin-7(1*H*)-one (11). To a stirred solution of 1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**1**) (107.2 mg, 0.36 mmol) in EtOH (4 ml), Hünig's base (69 μl, 0.39 mmol) and 2-aminothiophenol (89.8 mg, 0.72 mmol) were added and the mixture was heated at reflux for 22 h. The reaction mixture was then allowed to cool to *ca.* 20 °C and the precipitate was filtered and recrystallized to afford the *title compound* **11** (149.1 mg, 99%) as brown needles, mp >300 °C (from PhCl), R_f 0.34 (*t*-BuOMe–hexane, 3 : 1); (found: C, 71.2; H, 4.2; N, 13.2. $C_{25}H_{18}N_4OS$ requires C, 71.1; H, 4.3; N, 13.3%); λ_{max}(DCM)/nm 234 (log ε 3.52), 271 inf (3.43), 323 (3.53), 413 (3.15), 520 (2.73), 566 inf (2.68), 602 inf (2.49); ν_{max}/cm^{-1} 3335w (Ar NH), 3201w (Ar NH), 3057w (Ar CH), 1588s, 1576s, 1554m, 1524s, 1511s, 1497s, 1492m, 1483m, 1452m, 1372m, 1314s, 1197m, 1142m, 1004s, 864m, 845m, 838m, 821m, 815m, 778m, 750s, 728m; δ_H(300 MHz, TFA-d_1) NH_2 exchanged 8.32 (2H, d, *J* 8.0), 7.94–7.67 (9H,

m), 7.56–7.43 (3H, m), 7.40 (1H, s), 7.31 (1H, s); δ_C(75 MHz, TFA-d_1) 164.1 (s), 163.0 (s), 152.3 (s), 151.3 (s), 142.2 (s), 140.6 (d), 138.2 (s), 135.8 (d), 135.2 (d), 134.7 (d), 134.3 (d), 133.6 (s), 132.8 (s), 132.0 (d), 130.7 (d), 129.7 (d), 127.4 (d), 126.5 (d), 126.2 (d), 122.7 (s), 99.6 (d); *m/z* (EI) 422 (M^+, 22%), 420 (M^+-2, 39), 405 (33), 389 (60), 299 (35), 271 (21), 211 (10), 168 (17), 125 (74), 97 (14), 93 (25), 84 (22), 77 (100), 65 (18), 63 (25), 56 (26), 51 (37).

4.4. Intramolecular cyclocondensation reactions

4.4.1. 1,3-Diphenyl-1,6-dihydro-[1,2,4]triazino[5,6-*b*]phenazin-4-ium 4-methylbenzenesulfonate (12). To a stirred solution of 6-(2-aminophenylamino) - 1,3 - diphenylbenzo[*e*] - [1,2,4]triazin-7(1*H*)-one (**9**) (150 mg, 0.37 mmol) in EtOH (5 ml), TsOH·H_2O was added (70.0 mg, 0.37 mmol) and the mixture heated at reflux for 10 min. The volatiles were removed *in vacuo* and the residue crystallized to afford the *title compound* **12** (160.9 mg, 78%) as blue needles, mp >300 °C (from DCM–MeOH, 1 : 2), R_f 0.31 (*t*-BuOMe); (found: C, 68.8; H, 4.4; N, 12.4. $C_{32}H_{25}N_5O_3S$ requires C, 68.7; H, 4.5; N, 12.5%); λ_{max}(DCM)/nm 229 (log ε 3.45), 242 inf (3.40), 297 (3.72), 560 (3.43), 620 inf (3.09); ν_{max}/cm^{-1} 3063w (Ar CH), 1524s, 1504s, 1493m, 1391m, 1333m, 1151s, 1123m, 1030m, 1007s, 872m, 854m, 797m; δ_H(300 MHz, TFA-d_1) NH exchanged 7.77 (2H, d, *J* 7.7), 7.65–7.43 (12H, m), 7.39–7.31 (3H, m), 7.17 (2H, d, *J* 7.9), 6.46 (1H, s, *H*-12), 3.00 (3H, s, CH_3); δ_C(75 MHz, TFA-d_1) 151.1 (*C*=O), 146.2 (s), 146.0 (s), 145.3 (s), 144.6 (s), 142.8 (s), 141.1 (s), 138.4 (s), 135.4 (d), 134.4 (d), 133.7 (d), 132.5 (d), 132.2 (d), 131.5 (s), 131.0 (d), 130.9 (d), 129.6 (s), 128.0 (s), 128.0 (d), 127.2 (d), 126.0 (d), 120.6 (d), 119.8 (d), 99.5 (d), 95.5 (d), 21.2 (*C*H_3); *m/z* (EI) 388 (M^++1, 34%), 387 (M^+, 100), 310 (7), 296 (7), 283 (13), 128 (9), 77 (16).

4.4.2. 1,3-Diphenyl-1,6-dihydro-[1,2,4]triazino[5,6-*b*]phenazine (13). To a stirred solution of 6-(2-aminophenylamino)-1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**9**) (55.3 mg, 0.136 mmol) in EtOH (4 ml), TsOH·H_2O was added (26.0 mg, 0.137 mmol) and the mixture heated at reflux for 10 min, then cooled to *ca.* 20 °C and poured into iced water (20 ml). The precipitate that formed (44.3 mg) was filtered, dissolved in DCM (20 ml) and washed with NaOH 10% (15 ml). The organic layer was dried (Na_2SO_4), filtered and concentrated *in vacuo* to give the *title compound* **13** (22.8 mg, 43%) as blue needles, mp >300 °C (from PhH); (found: C, 77.4; H, 4.4; N, 18.0. $C_{25}H_{17}N_5$ requires C, 77.5; H, 4.4; N, 18.1%); λ_{max}(DCM)/nm 253 (log ε 3.92), 290 (3.97), 514 (3.60), 612 inf (2.87) ν_{max}/cm^{-1} 1569m, 1516m, 1490m, 1449s, 1332m, 1321m, 890m, 772m, 753m; *m/z* (EI) 388 (M^++1, 25%), 387 (M^+, 100), 103 (19), 77 ($C_6H_5^+$, 42), 71 (14), 69 (17), 57 (18), 55 (19), 51 (15).

4.4.3. 1,3-Diphenyl-1*H*-[1,2,4]triazino[6,5-*b*]phenothiazine (14). To a solution of 6-(2-aminophenylthio)-1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**11**) (155.5 mg, 0.37 mmol) in EtOH (9 ml) TsOH·H_2O (72.0 mg, 0.38 mmol) was added and the mixture was heated at reflux for 20 min then cooled to *ca.* 20 °C and poured into iced water (20 ml). The precipitate that formed was filtered, dissolved in DCM (25 ml) and washed with NaOH 10% (20 ml). The organic layer was dried (Na_2SO_4), filtered and concentrated *in vacuo* to give the *title compound* **14** (121.3 mg, 82%) as green needles, mp 256–260 °C (from PhCl), R_f 0.84 (*t*-BuOMe–hexane, 3 : 1); (found: C, 74.3; H, 4.1; N, 14.0. $C_{25}H_{16}N_4S$ requires C, 74.2; H, 4.0; N, 13.9%); λ_{max}(DCM)/nm 245 (log ε 3.42), 304 (3.52), 315 inf (3.49), 349 inf (3.18), 399 inf (2.80), 463 inf (2.89), 488 (2.58), 517 (3.15), 674 (2.52), 623 inf (2.56); ν_{max}/cm^{-1} 3065w (Ar CH), 1591m, 1518s, 1493m, 1476m, 1452s, 1310m, 972m, 862m, 847m, 781m; δ_H(300 MHz, TFA-d_1) 7.96 (2H, d, *J* 8.8), 7.82 (1H, br s), 7.73–7.61 (5H, m), 7.53–7.47 (3H, m), 7.43–7.32 (2H, m), 7.26–7.20 (2H, m), 6.70 (1H, br s); δ_C(75 MHz, TFA-d_1) 154.1 (s), 153.8 (s), 146.9 (s), 143.9 (s), 143.3 (s), 141.2 (s), 135.7 (d), 135.1 (d), 134.3 (d), 133.6 (s), 132.2 (d), 131.0 (d), 130.8 (d), 128.7 (s), 128.5 (d), 127.9 (d), 125.8 (d), 122.0 (s), 122.0 (d), 115.2 (d), 96.8 (d); *m/z* (EI) 405 (M^++1, 39%), 404 (M^+, 100), 196 (25), 77 (23), 51 (11).

4.4.4. 1,3,11-Triphenyl-1,6-dihydro-[1,2,4]triazino[5,6-*b*]phenazin-11-ium 4-methylbenzenesulfonate (15). To a stirred solution of 6-[2-(*N*-phenylamino)anilino]-1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**10**) (54.7 mg, 0.11 mmol) in EtOH (3 ml), TsOH·H_2O (19.5 mg, 0.11 mmol) was added and the mixture heated at reflux for 15 min. The reaction mixture was cooled to 0 °C and then filtered to give the *title compound* **15** (69.0 mg, 99%) as blue needles, mp 245–248 °C (from EtOH), R_f 0.57 (*t*-BuOMe); (found: C, 71.0, H, 4.8, N, 10.6. $C_{38}H_{29}N_5O_3S$·1/2 EtOH requires C, 71.1; H, 4.9; N, 10.6%); λ_{max}(DCM)/nm 308 (log ε 3.77), 320 inf (3.67), 401 (2.61), 534 inf (3.17), 574 (3.50), 620.1 (3.59); λ_{max}(EtOH)/nm 305 (log ε 4.11), 428 (3.06), 530 inf (3.50), 569 (3.80), 613 (3.86); ν_{max}/cm^{-1} 3414w (NH), 3061w (Ar CH), 1514s, 1499m, 1468m, 1393m, 1161m, 1121m, 1034m, 1007m; δ_H(300 MHz, $CDCl_3$) 13.09 (1H, s, N*H*), 8.06 (2H, d, *J* 7.1), 7.86 (2H, d, *J* 8.0), 7.62 (2H, dd, *J* 7.5, 7.5), 7.52–7.34 (12H, m), 7.14 (2H, d, *J* 7.9), 7.07 (1H, s), 6.75 (1H, dd, *J* 7.2, 7.2), 6.55 (1H, dd, *J* 7.5, 7.5), 6.07 (1H, d, *J* 8.1), 5.31 (1H, s, *H*-12), 3.71 (1H, q, *J* 7.0, CH_3CH_2OH), 2.32 (3H, s, CH_3), 1.23 (1.5H, t, CH_3CH_2OH); δ_C(75 MHz; $CDCl_3$) one Ar *C* missing 159.3 (s), 154.4 (s), 145.4 (s), 144.3 (s), 143.5 (s), 140.3 (s), 139.6 (s), 138.8 (s), 135.8 (s), 133.7 (s), 131.8 (d), 131.5 (d), 130.9 (d), 130.6 (d), 130.4 (s), 130.0 (d), 128.9 (d), 128.6 (d), 128.1 (d), 127.6 (d), 127.5 (d), 126.4 (d), 125.8 (d), 125.2 (d), 118.5 (d), 116.5 (d), 102.9 (d), 92.3 (d), 21.6 (*C*H_3); *m/z* (EI) 464 (M^++1, 33%), 463 (M^+, 100), 386 (8), 372 (8), 255 (23), 231 (8), 178 (6), 128 (11), 77 (22).

4.4.5. 1,3,11-Triphenyl-1*H*-[1,2,4]triazino[5,6-*b*]phenazin-11-ium-6-ide (16). To a stirred solution of 6-[2-(*N*-phenylamino)anilino]-1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**10**) (64 mg, 0.12 mmol) in EtOH (3 ml), TsOH·H_2O (22.8 mg; 0.12 mmol) was added and the mixture heated at reflux for 20 min. On cooling to *ca.* 20 °C the reaction mixture was then diluted (DCM, 30 ml) and washed (10% KOH, 15 ml). The organic layer was separated, dried (Na_2SO_4) and evaporated *in vacuo*. The residue obtained was triturated (DCM–MeOH 1 : 3) to give the *title compound* **16** (55.1 mg; 87%) as blue needles, mp >300 °C (from PhH), R_f 0.30 (*t*-BuOMe); (found: C, 80.3, H, 4.4, N, 15.0. $C_{31}H_{21}N_5$ requires C, 80.3; H, 4.6; N, 15.1%); λ_{max}(CCl_4)/nm 407 (2.31), 426 (log ε 2.40), 480 (2.18), 513 (2.18), 564 inf (2.26), 607 (2.39), 657 (2.37); λ_{max}(PhMe)/nm 307 (log ε 2.86), 316 (2.78), 403 (2.33), 426 (2.43), 478 (2.22), 510 (2.23), 556 inf (2.28), 601 (2.43), 650 (2.40); λ_{max}(1,4-dioxane)/nm 307 (log ε 3.44), 313 inf (3.37), 403 inf (2.80), 426 (2.92), 477 (2.63), 508 (2.67), 550 inf (2.76), 593 (2.98), 643 (2.95); λ_{max}($CHCl_3$)/nm 306 (log ε 3.70), 406 inf (3.02), 427 (3.13), 477 (2.81), 508 (2.80), 550 inf (3.02), 591 (3.29), 637 (3.29); λ_{max}(DCM)/nm 307 (log ε 3.97), 404 inf

(3.27), 426 (3.39), 477 (3.09), 506 (3.12), 548 inf (3.29), 590 (3.55), 635 (3.55); λ_{max}(MeCN)/nm 304 (log ε 3.51), 402 inf (2.83), 425 (2.93), 476 (2.68), 505 (2.74), 541 inf (2.85), 584 (3.09), 628 (3.08); λ_{max}(EtOH)/nm 303 (log ε 3.48), 406 (2.79), 427 (2.86), 476 (2.60), 541 inf (2.82), 583 (3.09), 624 (3.10); λ_{max}(MeOH)/nm 302 (log ε 3.43), 404 (2.72), 426 (2.78), 475 (2.59), 537 inf (2.81), 574 (3.07), 615 (3.09); λ_{max}(H^+/EtOH)/nm 305 (log ε 3.88), 368 (2.75), 527 inf (3.29), 567 (3.61), 613 (3.67); ν_{max}/cm^{-1} 3049w, 1514s, 1393m; δ_H(300 MHz; TFA-d_1) 7.27 (2H, d, *J* 7.4), 7.07–7.01 (5H, m), 6.97–6.84 (7H, m), 6.79–6.76 (3H, m), 6.71–6.68 (2H, m), 6.20 (1H, d, *J* 7.9), 5.17 (1H, s, *H*-12); δ_C(75 MHz; TFA-d_1) 151.8 (s), 146.3 (s), 145.1 (s), 144.5 (s), 144.4 (s), 140.8 (s), 136.0 (s), 135.9 (d), 134.7 (s), 134.4 (d), 133.8 (d), 133.6 (d), 133.5 (d), 132.4 (d), 131.8 (d), 131.0 (d), 129.8 (s), 128.0 (d), 127.7 (s), 127.7 (d), 125.6 (d), 121.1 (d), 119.7 (d), 99.2 (d), 96.7 (d); *m*/*z* (EI) 464 (M^++1, 32%), 463 (M^+, 100), 255 (24), 232 (12), 178 (7), 77 (36).

4.4.6. 6-(Methoxycarbonyl)-7-oxo-1,3-diphenyl-7*H*-benzofuro[5,6-*e*][1,2,4]triazin-1-ium-4-ide (17). To a stirred solution of 1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**1**) (50 mg, 0.167 mmol) in MeOH (1.5 ml), dimethyl malonate (20 μl, 0.174 mmol) and Hünig's base (28 μl, 0.167) were added. The mixture was refluxed for 6 h. TLC (*t*-BuOMe–hexane, 3 : 1) showed the absence of the starting material and the presence of a new less polar green product. Dry flash chromatography (*t*-BuOMe–hexane, 2 : 1) of the residue gave the *title compound* **17** (49 mg, 74%) as green needles, mp 272–268 °C (DCM–MeOH, 1 : 3), R_f 0.29 (*t*-BuOMe–hexane, 3 : 1); (found: C, 69.5; H, 3.7; N, 10.6. $C_{23}H_{15}N_3O_4$ requires C, 69.5; H, 3.8; N, 10.6%); λ_{max}(CCl_4)/nm 282 (log ε 3.20), 297 inf (3.09), 357 (2.98), 376 (2.94), 432 (2.44), 457 (2.47), 554 inf (2.40), 600 (2.51), 651 (2.52), 732 inf (2.37); λ_{max}(PhMe)/nm 358 (log ε 3.24), 374 (3.23), 429 (2.66), 457 (2.74), 550 inf (2.62), 592 inf (2.80), 645 (2.88), 711 inf (2.74); λ_{max}(1,4-dioxane)/nm 280 (log ε 3.45), 297 inf (3.33), 353 (3.27), 368 (3.27), 419 inf (2.65), 449 (2.74), 580 inf (2.81), 628 (2.88), 688 inf (2.75); λ_{max}($CHCl_3$)/nm 280 (log ε 3.44), 298 inf (3.33), 354 (3.27), 366 (3.27), 427 inf (2.69), 453 (2.80), 585 (2.80), 635 (2.86), 698 inf (2.74); λ_{max}(DCM)/nm 279 (log ε 3.40), 298 inf (3.29), 353 (3.22), 364 (3.21), 429 inf (2.64), 452 (2.74), 586 inf (2.75), 629 (2.81), 686 inf (2.69); λ_{max}(MeCN)/nm 275 (log ε 3.42), 295 inf (3.34), 352 (3.29), 444 (2.82), 606 (2.89); λ_{max}(EtOH)/nm 277 (log ε 3.42), 295 inf (3.32), 351 (3.27), 444 (2.83), 600 (2.86); λ_{max}(MeOH)/nm 257 inf (log ε 3.50), 276 (3.58), 295 inf (3.47), 348 (3.44), 443 (3.01), 594 (3.03); ν_{max}/cm^{-1} 3065w, 1761m, 1468s, 1421s, 1396m, 1261m, 1217m, 1144m, 982m, 781m; δ_H(300 MHz, $CDCl_3$) 8.44 (2H, dd, *J* 7.8, 1.6), 8.09 (1H, s), 7.80–7.75 (3H, m), 7.71–7.68 (2H, m), 7.58–7.51 (3H, m), 6.92 (1H, s, *H*-9), 3.92 (OCH_3); δ_C(75 MHz, $CDCl_3$) one Ar *C* missing 166.2 (s), 164.6 (s), 161.1 (s), 159.2 (s), 148.6 (s), 148.0 (s), 141.5 (s), 135.7 (s), 133.9 (s), 132.2 (d), 130.6 (d), 129.2 (d), 128.2 (d), 125.7 (d), 107.3 (d), 92.8 (d), 88.0 (s), 51.7 (CH_3); *m*/*z* (EI) 398 (M^++1, 25%), 397 (M^+, 100), 366 (82), 339 (55), 282 (17), 180 (9), 103 (9), 77 (57), 51 (18).

4.5. Intermolecular cycloaddition reaction

4.5.1. [5,6-*c*]-Thiadiazolo-1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (22). To a stirred solution of 1,3-diphenylbenzo[*e*][1,2,4]triazin-7(1*H*)-one (**1**) (40.0 mg, 0.133 mmol) in DMF (2 ml), S_4N_4 (122.4 mg, 0.665 mmol) was added and the reaction mixture was heated at reflux for 1 h or until all the starting material was consumed (by TLC). The mixture was allowed to cool to *ca.* 20 °C, diluted with DCM and washed with H_2O. The organic layer was separated, dried and loaded on silica. Dry flash chromatography (ether–DCM, 1 : 1) gave the *title compound* **22** (7 mg, 15%) as brown crystals, mp 285–290 °C (from PhCl); (found: C, 63.9; H, 3.1; N, 19.7. $C_{19}H_{11}N_5OS$ requires C, 63.9; H, 3.1; N, 19.6%); λ_{max}(DCM)/nm 271 (log ε 3.69), 309 (3.81), 407 (3.39), 541 (2.73); ν_{max}/cm^{-1} 1619s (C═O), 1601m, 1589m, 1573m, 1520s, 1505s, 1489m, 1464m, 1454m, 1438m, 1412m, 1354m, 1250m, 1239s, 1160m, 1153m, 904m, 855m, 833s, 826s, 796m, 790m, 782s, 770s; δ_H(300 MHz; $CDCl_3$) 8.42–8.32 (2H, m), 7.70–7.57 (5H, m), 7.57–7.48 (3H, m), 6.25 (1H, s, *H*-5); δ_C(75 MHz; $CDCl_3$) 173.1 (*C*═O), 157.8 (s), 152.7 (s), 150.8 (s), 150.0 (s), 141.2 (s), 139.8 (s), 132.9 (s), 131.2 (d), 130.5 (d), 130.4 (d), 128.9 (d), 127.0 (d), 124.9 (d), 98.3 (d); *m*/*z* (EI) 358 (M^++1, 15%), 357 (M^+, 47), 340 (13), 226 (24), 174 (13), 142 (19), 103 (29), 86 (14), 77 ($C_6H_5^+$, 100), 63 (14), 51 (55). Further elution (ether) gave the orange 6-amino-1,3-diphenylbenzo[*e*][1,2,4]triazin-7-(1*H*)–one (**23**) (20 mg, 48%) mp 279–282 °C (lit.,[4] 279–282 °C) (from PhH), R_f 0.21 (*t*-BuOMe–hexane, 3 : 1); (found: C, 72.7; H, 4.4; N, 17.9. $C_{19}H_{14}N_4O$ requires C, 72.6; H, 4.5; N, 17.8%); λ_{max}(DCM)/nm 274 (log ε 3.49), 302 inf (3.46), 312 (3.48), 332 inf (3.29), 401 inf (3.25), 417 (3.30), 504 (2.60); ν_{max}/cm^{-1} 3416w (Ar NH), 1581m, 1566m, 1555s, 1541s, 1491m, 824m; δ_H(300 MHz; TFA-d_1) NH peak missing 8.09 (2H, d, *J* 7.6), 7.78–7.64 (7H, m), 7.58–7.48 (3H, m); *m*/*z* (EI) 315 (M^++1, 23%), 314 (M^+, 100), 286 (12), 104 (13), 77 (100), 51 (61) identical to an authentic sample.

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References

1 F. A. Neugebauer and I. Umminger, *Chem. Ber.*, 1980, **113**, 1205.
2 P. A. Koutentis and D. Lo Re, *Synthesis*, 2010, 2075.
3 C. P. Constantinides, P. A. Koutentis, H. Krassos, J. M. Rawson and A. J. Tasiopoulos, *J. Org. Chem.*, 2011, **76**, 2798.
4 P. A. Koutentis, H. Krassos and D. Lo Re, *Org. Biomol. Chem.*, 2011, **9**, 5228.
5 P. A. Koutentis, G. Loizou and D. Lo Re, *J. Org. Chem.*, 2011, **76**, 5793.
6 H. A. Ioannidou, A. Martin, A. Gollner and P. A. Koutentis, *J. Org. Chem.*, 2011, **76**, 5113.
7 A. Gollner and P. A. Koutentis, *Org. Lett.*, 2010, **12**, 1352.
8 J. Geevers and W. P. Trompen, *Recl. Trav. Chim. Pays-Bas*, 1974, **93**, 270.
9 P. A. Koutentis and C. W. Rees, *J. Chem. Soc., Perkin Trans. 1*, 2000, 2601.
10 C. Reichardt, in *Solvent Effects in Organic Chemistry*, pp. 189–205, Verlag Chemie, Weinheim (1979).
11 P. A. Koutentis, *Arkivoc*, 2002, **vi**, 175.
12 F. Wudl, P. A. Koutentis, A. Weitz, B. Ma, T. Strassner, K. N. Houk and S. I. Khan, *Pure Appl. Chem.*, 1999, **71**, 295.

13 K. Hutchison, G. Srdanov, R. Hicks, H. N. Yu, F. Wudl, T. Strassner, M. Nendel and K. N. Houk, *J. Am. Chem. Soc.*, 1998, **120**, 2989.
14 L. Beer, R. T. Oakley, J. R. Mingie, K. E. Preuss and N. J. Taylor, *J. Am. Chem. Soc.*, 2000, **122**, 7602.
15 P. Braunstein, O. Siri, J. P. Taquet, M. M. Rohmer, M. Bénard and R. Welter, *J. Am. Chem. Soc.*, 2003, **125**, 12246.
16 O. Siri and P. Braunstein, *Chem. Commun.*, 2002, 208.
17 O. Siri, P. Braunstein, M. M. Rohmer, M. Bénard and R. Welter, *J. Am. Chem. Soc.*, 2003, **125**, 13793.
18 P. Langer, A. Bodtke, N. N. R. Saleh, H. Görls and P. R. Schreiner, *Angew. Chem., Int. Ed.*, 2005, **44**, 5255.
19 C. Reichardt in *Solvent Effects in Organic Chemistry*, pp. 242–244, Verlag Chemie, Weinheim (1979).
20 J. Kruszewski and T. M. Krygowski, *Tetrahedron Lett.*, 1972, **13**, 3839.
21 U. C. Singh and P. A. Kollman, *J. Comput. Chem.*, 1984, **5**, 129.
22 R. C. Binning Jr. and L. A. Curtiss, *J. Comput. Chem.*, 1990, **11**, 1206.
23 H. Onkawa, N. Ohiehi and K. Yagi, *Anal. Biochem.*, 1979, **96**, 351.
24 J. Buyan, J. Green, E. E. Edwin and T. Diplock, *Biochem. J.*, 1960, **77**, 47.
25 P. A. Koutentis, in *Science of Synthesis*, Volume 13, Product Class 11, Editors R. C. Storr, T. L. Gilchrist, pp. 297–348.
26 P. A. Koutentis, in *Comprehensive Heterocyclic Chemistry III*, Volume 5, Chapter 5.09, Volume Editor V. V. Zhdankin, 515–565, 2008.
27 S. T. A. K. Daley and C. W. Rees, *J. Chem. Soc., Perkin Trans. 1*, 1987, 203.
28 S. T. A. K. Daley and C. W. Rees, *J. Chem. Soc., Perkin Trans. 1*, 1987, 207.
29 V. Bertini, A. D. Munno and A. Marraccini, *J. Org. Chem.*, 1972, **37**, 2587.
30 A. P. Scott and L. Radom, *J. Phys. Chem.*, 1996, **100**, 16502.
31 M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, J. A. Montgomery Jr., T. Vreven, K. N. Kudin, J. C. Burant, J. M. Millam, S. S. Iyengar, J. Tomasi, V. Barone, B. Mennucci, M. Cossi, G. Scalmani, N. Rega, G. A. Petersson, H. Nakatsuji, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, M. Klene, X. Li, J. E. Knox, H. P. Hratchian, J. B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, P. Y. Ayala, K. Morokuma, G. A. Voth, P. Salvador, J. J. Dannenberg, V. G. Zakrzewski, S. Dapprich, A. D. Daniels, M. C. Strain, O. Farkas, D. K. Malick, A. D. Rabuck, K. Raghavachari, J. B. Foresman, J. V. Ortiz, Q. Cui, A. G. Baboul, S. Clifford, J. Cioslowski, B. B. Stefanov, G. Liu, A. Liashenko, P. Piskorz, I. Komaromi, R. L. Martin, D. J. Fox, T. Keith, M. A. Al-Laham, C. Y. Peng, A. Nanayakkara, M. Challacombe, P. M. W. Gill, B. Johnson, W. Chen, M. W. Wong, C. Gonzalez, J. A. Pople, *Gaussian 03, Revision C.02*, Gaussian, Wallingford, CT, 2004.
32 K. Wolinski, J. F. Hilton and P. Pulay, *J. Am. Chem. Soc.*, 1990, **112**, 8251.
33 L. M. Harwood, *Aldrichimica Acta*, 1985, **18**, 25.

