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Reaction of (1,3-dioxo-2,3-dihydro-1*H*-inden-2-ylidene)propanedinitrile with *N*-arylisoindolines

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Dedicated to Professor Howard E. Zimmerman for four decades of friendship

Abstract—In a multistep reaction, 3,3′-(2-aryl-2*H*-isoindol-1,3-ylene)-di-(1,4-naphthoquinone-2-carbonitriles) **13a–f** have been formed in 25–61% yield from a series of *N*-arylisoindolines **8a–f** with (1,3-dioxo-2,3-dihydro-1*H*-inden-2-ylidene)propanedinitrile (**1**) in aerated pyridine. The structure of one of these products (**13f**) has been unambiguously confirmed by a single crystal X-ray structure analysis. Under otherwise the same conditions, 2-(3-methoxyphenyl)-isoindoline (**8g**) and **1** gave 38% of [4-(2,3-dihydro-1*H*-isoindol-2-yl)-2-methoxyphenyl]-1,3-dioxoindan-2-ylidene)acetonitrile (**15**). Rationales for these conversions involving the known rearrangement of the radical anion of **1** into the radical anion of 1,4-naphthoquinone-2,3-dicarbonitrile (**3**) are presented.

1. Introduction

(1,3-Dioxo-2,3-dihydro-1*H*-inden-2-ylidene)propanedinitrile (**1**, also referred to as 2-(dicyanomethylene)-1,3-indanedione, see Chart 1) may be considered to be analogous to ethenetetracarbonitrile (**2**) in its reactions. Like the latter it readily adds *N*-nucleophiles such as secondary aliphatic[1] and primary aromatic amines[2] at the dicyanomethylene carbon atom with release of hydrogen cyanide analogously to the corresponding reactions of **2**.[3] Tertiary aromatic amines (like *N*,*N*-dimethylaniline) are prone to attack with their *p*-carbon atom, followed by release of HCN.[2b,4]

Like **2**, acceptor **1** is also able to generate iminium ions **6** from the tertiary cyclic amines **4a** and **4b** in ethanol or acetonitrile solution.[5] Cyanide ion released from the anion **5** in turn intercepts **6** to generate the α-cyanated amines **7** (Scheme 1).[5]

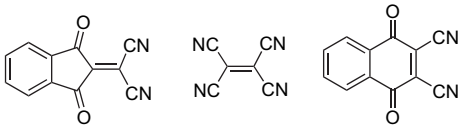
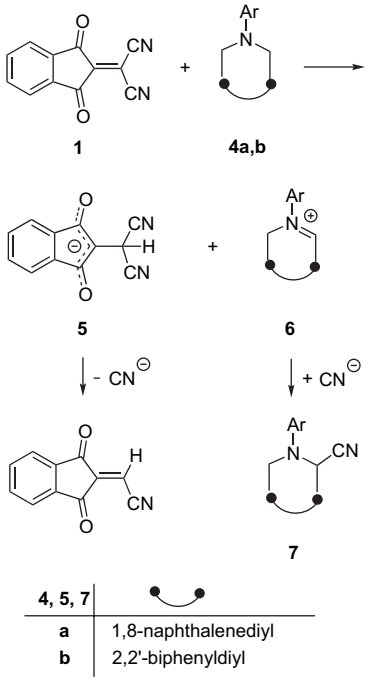


Chart 1.



Ar = R-C_6H_4 with R = H, 4-Me, 4-OMe, 4-Cl

Scheme 1.

Keywords: Donor–acceptor interactions; 2*H*-Isoindoles; Merocyanines; Rearrangement; Radical ions; X-ray crystal structure analysis.
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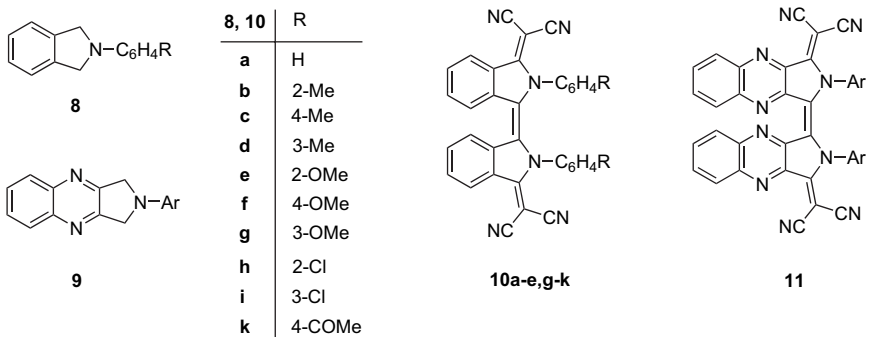


8, 10	R
a	H
b	2-Me
c	4-Me
d	3-Me
e	2-OMe
f	4-OMe
g	3-OMe
h	2-Cl
i	3-Cl
k	4-COMe

Chart 2.

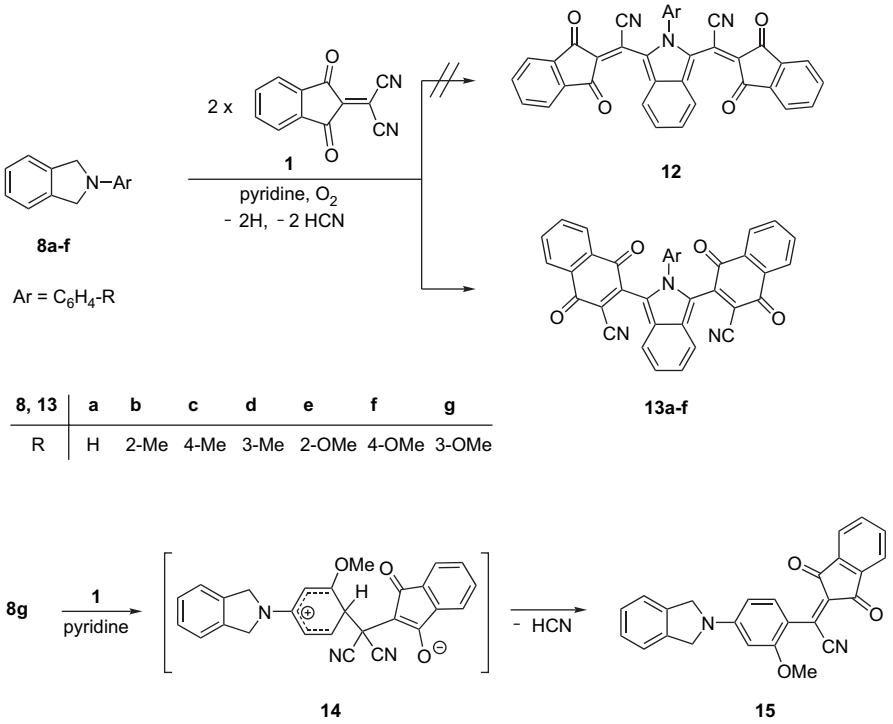
Recently we have reported an efficient transformation of 2-arylisoindolines (2-aryl-1,3-dihydro-2*H*-isoindoles) **8a–e**,**g–k** with **2** into the *cis*-isoindigo like compounds **10**[6] (Chart 2). Closely analogous compounds **11** had been obtained from dihydropyrrolo[3,4-*b*]quinoxalines **9** and **2**.[7] Also (2,4,7-trinitro-9*H*-fluoren-9-ylidene)propanedinitrile has acted as an dicyanomethylenating agent on isoindolines **8**.[8]

This paper is focused on the reactions of the acceptor **1** with isoindolines **8**. The latter compounds and the aforementioned amines **4a** and **4b** (Scheme 1) have in common the methylene groups α to nitrogen that do enjoy benzylic activation, and **4b** may be looked at as a phenylene homologue of **8**.[5] We therefore were interested in clarifying how **1**, which needs to be treated in context with its isomeric quinone **3**[9] (see chart 1), reacts with isoindolines **8**.

2. Results

Solutions of **8a–g** (1 mmol each) in 10 mL of dry pyridine were added dropwise to solutions of **1** (2 mmol) in 20 mL of the same solvent. The mixtures were gently warmed to 50–60 °C and kept at this temperature for 3 h with stirring and admission of air and were finally warmed to 100 °C for 3 min. The residue obtained from concentration at 50 °C consisted of a complex mixture containing a deep blue main component and numerous coloured byproducts each in small quantities. From their gross composition and spectroscopic evidence the main products from **8a–f** were found to be formed from two molecules of **1** and one molecule of **8a–f** by loss of 2H and two molecules of HCN. Thus, both a net didehydrogenation and a twofold reaction analogous to a tricyanovinylation[3] were suspected to have taken place at C-1 and C-3 of **8**.

Therefore, structure **12** (Scheme 2) was assigned to the main products first but later, mainly on the basis of a single crystal X-ray structure determination of **13f**, replaced by **13**. Thus the skeletal rearrangement of reactant **1** to the connectivity of the quinone **3** had taken place under the reaction conditions, a phenomenon observed earlier in a different context by Bryce et al.[9]



8, 13	a	b	c	d	e	f	g
R	H	2-Me	4-Me	3-Me	2-OMe	4-OMe	3-OMe

Scheme 2.

Table 1. Visible absorptions of compounds **13a–f** in acetonitrile

13	a	b	c	d	e	f
λ_{max} [nm]	648	660	650	648	668	654
log ε	3.9	4.0	4.1	3.9	4.0	4.2

The visible absorptions in acetonitrile solution are around 650 nm for **13a**,**c**,**d** and **f** and somewhat higher for **13b** and **13e** bearing *o*-substituted phenyl groups on the isoindole nitrogen (Table 1). The IR spectra are characterized by weak CN-absorptions (2220–2230 cm^{-1}) characteristical for CN groups in systems heavily substituted with polar electron attracting groups[10] and two carbonyl absorptions (1675–1665 and 1660–1645 cm^{-1}) as expected.

NMR spectroscopy was hampered by insufficient solubility in $CDCl_3$, so CD_3NO_2 and DMF-d_7 had to be used. Raising the temperature to 70 °C (in the cases of **13b** and **13f**) did improve the solubility but was insufficient to accelerate internal rotations to a suitable extent to simplify spectra. In general, partial decomposition and/or precipitation had been observed when long measuring times had to be applied. Still, both the ^1H and ^{13}C NMR spectra (we restrict the presentation to the two examples **13b** and **13f**) are in accord with the proposed structures.

Unambiguous support for these came from the X-ray structure analysis of **13f** (see Fig. 1 and Table 2, note that the crystallographic numbering does not reflect the systematic numbering). Since the molecule **13f** from its connectivity may be divided in two symmetrical halves, the emphasis in Table 2 has been laid on grouping corresponding bonds and angles within or close to the main chromophore. The sum of the angles around the isoindole N atom (C1–N1–C9, C8–N1–C9 and C1–N1–C8) is close to 360° suggesting planarity around N1. Due to steric encumbering there is a substantial twisting of the anisyl and naphthoquinonyl groups out of the plane of the isoindolylene moiety. Least squares planes for these groups have been defined as follows: Plane 1 (pyrrol ring) by N1–C1–C2–C7–C8, plane 2 (anisyl group) by C9–C10–C11–C12–C13–C14, plane 3 (C1-naphthoquinonyl) by C16–C17–C18–C23–C24–C25 and plane 4 (C8-naphthoquinonyl) by C36–C37–C38–C43–C44–C45. The twist angles with respect to plane 1 are 53.99(3)° for the anisyl group (plane 2), 41.07(2)° and 48.84(2)° for the C1- and C8-naphthoquinonyl groups (planes 3 and 4), respectively.

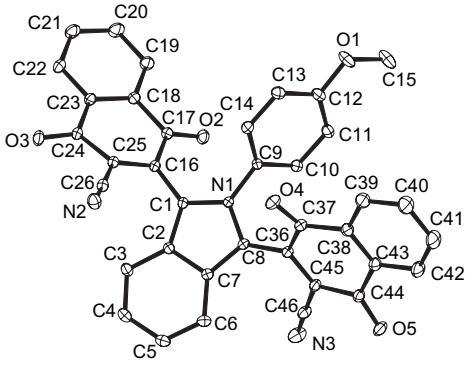


Figure 1. Molecular structure of compound **13f** in the crystal. The crystallographic numbering does not reflect the systematic numbering. Anisotropic displacement parameter ellipsoid is drawn at 50% probability.

Table 2. Selected bond lengths and bond angles of compound **13f**

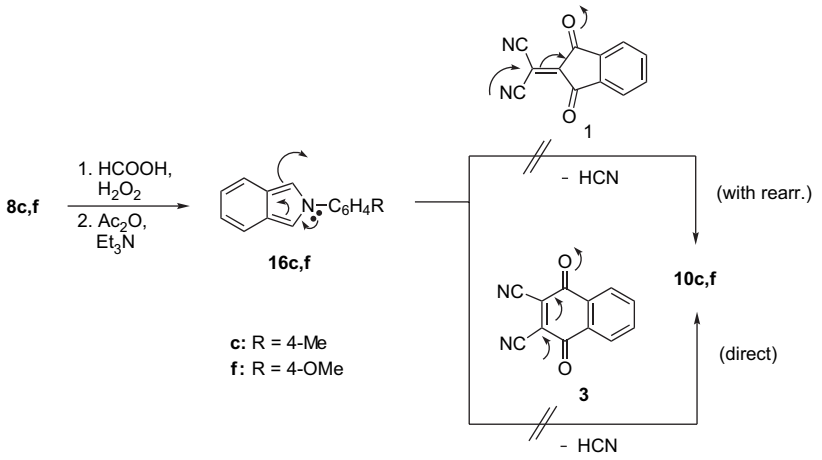
Bond lengths (Å):			
C4–C5	1.4166(15)	C2–C7	1.4247(13)
Bond lengths listed in pairs of corresponding bonds (Å)			
C1–C2	1.4212(13)	C7–C8	1.4115(13)
C2–C3	1.4120(14)	C6–C7	1.4132(13)
C3–C4	1.3754(14)	C5–C6	1.3733(15)
C1–N1	1.3797(12)	C8–N1	1.3692(12)
C1–C16	1.4359(13)	C8–C36	1.4514(13)
C16–C17	1.5060(13)	C36–C37	1.5111(14)
C17–O2	1.2174(12)	C37–O4	1.2172(12)
C16–C25	1.3719(25)	C36–C45	1.3570(13)
C25–C26	1.4349(14)	C45–C46	1.4375(14)
C26–N2	1.1529(14)	C46–N3	1.1486(14)
C24–C25	1.4753(13)	C44–C45	1.4853(13)
C24–O3	1.2270(12)	C44–O5	1.2210(12)
Bond angles (°), listed in pairs of corresponding angles			
C1–N1–C8	110.36(8)		
C1–N1–C9	127.66(8)	C8–N1–C9	121.93(8)
N1–C1–C16	127.09(9)	N1–C8–C36	128.29(9)
C2–C1–C16	125.79(9)	C7–C8–C36	128.29(9)
C2–C1–N1	107.12(8)	C7–C8–N1	108.32(8)
C1–C16–C17	122.19(8)	C8–C36–C37	117.72(8)
C1–C16–C25	118.99(9)	C8–C36–C45	122.94(9)
C17–C16–C25	118.56(8)	C37–C36–C45	118.91(9)

In contrast to the results with **8a–f**, a different product (**15**) was obtained from **8g** (Scheme 2, bottom). The gross formula $C_{26}H_{18}N_2O_3$ is confirmed by its mass spectrum (M^+ at m/z=406), which also shows fragments for loss of CN and CO. The ^1H NMR clearly demonstrates the isoindoline structure by the presence of a 4H singlet at 4.81 ppm (in $CDCl_3$) for the methylene protons and a negative signal in the ^{13}C DEPT 135 spectrum at 55.2 ppm. Also, the ^{13}C carbonyl resonances (in CD_3NO_2) are found at 188.1 and 189.0 ppm compared to 160 ppm (in DMF-d_7) for **13f**. It should be pointed out that from this spectral information the indanedione moiety had not been rearranged to a quinonyl residue as in **13a–f**. In addition, it was corroborated in a separate test experiment that **8g** and the quinone **3** in pyridine did not form **15**, which therefore is the product of an electrophilic attack of the exocyclic methylene C of **1** on the phenyl p-C of **8g** with release of HCN analogous to a tricyanovinylation.[4]

3. Discussion

Clearly, the transformation of **8a–f** with **1** to **13a–f** must involve a multitude of steps and is necessarily complex. Moderate yields as found and based throughout on the amount of starting material **8** used are therefore acceptable, and it will not be possible—except when unduly large efforts are made—to identify every byproduct and to clarify all details. Therefore, we will concentrate on the interplay between formation of the main products and the necessary skeletal rearrangement **1**→**3** in the light of the findings reported by Bryce et al.[9] who had demonstrated that **1** is isomerized to **3** when brought in contact with electron donors, e.g., tetrathiafulvalene.[9c]

It had been reported earlier[11] that isoindolines **8a**, **8c** and **8f** as well as other *p*-substituted 2-phenylisoindolines of type **8**



Scheme 3.

react with quinone **3** in ethyl acetate under admission of air to form *N*,*N*-diarylisoindigo structures and *not* compounds of type **13**. On the other hand, it has been known for more than half a century that quinones tend to abstract hydride ions from suitable donors giving eventually didehydrogenated products thereof,[12] and that this initial hydride abstraction may in fact be a two-step process involving radicals.[13] It was therefore felt necessary to rule out that a dehydrogenation of **8** to the corresponding 2*H*-isoindoles (like **16b** and **16c**) occurred and that these isoindoles react with either **1** or its isomer **3** (if formed under our reaction conditions). To test this possibility, 2-(4-methylphenyl) (**16c**) and 2-(4-methoxyphenyl)-2*H*-isoindole (**16f**) have been prepared according to the procedures published by Kreher.[14] Isoindole **16f** was chosen in spite of the low yield to be expected[14] in its preparation. To our surprise, neither **16c** nor **16f** gave the corresponding products **13c** and **13f**, respectively, upon reaction with doubled molar amounts of either **1** or **3** in aerated pyridine at 50–60 °C (Scheme 3). At this occasion, quinone **3** was found to be less stable than **1** in pyridine. These findings rendered the isoindoles **16** unlikely as intermediates.

Another point of concern is the fact that in **13** *two* quinonyl residues are attached to the isoindole skeleton with release of two molecules of HCN and thus these two consecutive introductions of the quinonyl residues have to be of equal (or almost equal) probability. It is hard to see how either **1** or **3** could react with isoindoles **16** in this way, since the introduction of the first quinonyl residue by whatever mechanism would decrease the electron richness of the isoindole unit due to conjugation with an acceptor and thus hamper the introduction of the second. Thus, 2*H*-isoindoles as **16a** and **16f** had to be ruled out as intermediates.

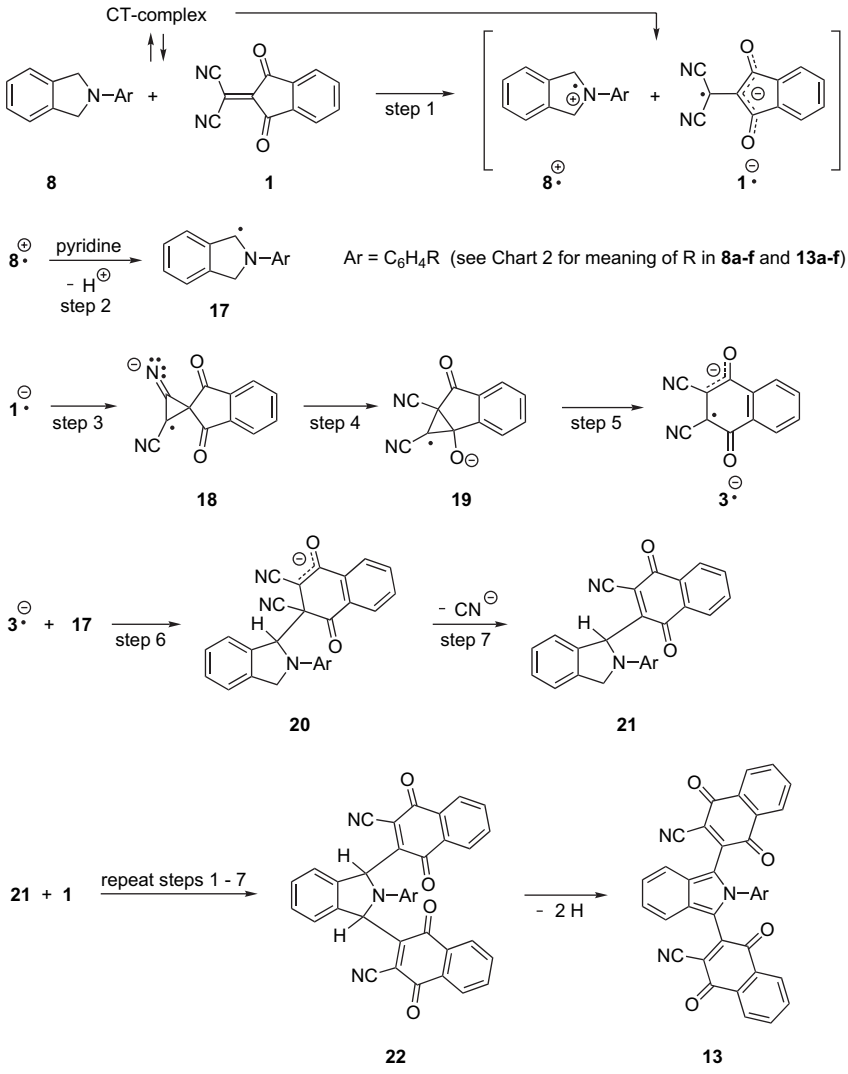
A rationale in accord with all findings and considerations is presented in Scheme 4. Charge transfer complexation of **8a–g** with **1** in dichloromethane has been observed[15] and may as well be operating in pyridine. Formation of a radical ion pair [$\mathbf{1}^{\bullet-}$/$\mathbf{8}^{\bullet+}$] may be envisaged (analogous to such ion pair formation from **2** and *N*,*N*-diethylaniline[16]) as the first chemical event, which is made likely by the observation of a green colouration attributed to the radical anion $\mathbf{1}^{\bullet-}$.[9] Next, the solvent pyridine abstracts a proton from the radical cation $\mathbf{8}^{\bullet+}$ to generate the α-amino radical **17**. In this way, back electron transfer with regeneration of the starting materials **1** and **8** is retarded. The anion radical $\mathbf{1}^{\bullet-}$ undergoes rearrangement[9] via intermediates **18** and **19** (steps 3–5) to form the anion radical $\mathbf{3}^{\bullet-}$, which combines with **17** to form **20**, which in turn by release of cyanide ion generates **21** (steps 6 and 7). In the latter compound, 3-CH_2 has a similar reactivity as 1-CH_2 had before, so steps 1–7 may well be repeated using the second molecule of **1**. At the end, the dihydroproduct **22** is didehydrogenated to **13** by air or any residual **1** or **3**.

In this treatment so far the introduction of the quinonyl groups into the products **13** is linked to the isomerization of **1** to the quinone structure. It could be argued, though, that the rearrangement of **1**→**3** could well take place independently and that isoindolines **8** would be attacked later by the quinone **3**. To test this possibility, **8f** was reacted with twofold molar amounts of **1** and **3** at otherwise the same conditions as in the preparative runs but in parallel semi-micro experiments. Whereas the preparative reaction between **8f** and **1** (see above) was perfectly matched, no **13f** was ever formed in the reactions of **8f** with **3**.

The question remains why **8g** does not follow the reaction pattern shown by **8a–f**. No formation of a product of type **13** is ever observed, also in semi-micro trials to react **8g** with **3**. Since **15** cannot be obtained from **8g** and the quinone **3**, its structure must be that of an indanedione and not that of a quinone derivative. Indeed, **8g** is the most suitable starting material (among **8a–g**) for electrophilic attack by **1** at the phenyl C-4 since the isoindoline nitrogen and the 3-methoxy group do combine their +M effects to stabilize intermediate **14** (Scheme 2) and thus the electron transfer process typical for **8a–f** and required for the formation of **13a–f** is no longer competitive.

4. Conclusion

Novel and interesting diquinone structures have been obtained from the interaction of electron rich 2-arylisoindolines **8** with the TCNE-analogous acceptor 2-(dicyanomethylene)-indane-1,3-dione (**1**). The skeletal rearrangement of **1** into a structure derived from **3**[9] is connected with the introduction of the



Scheme 4.

quinonyl residues at C-1 and C-3 of the starting materials. An independent isomerization of **1**→**3** prior to reaction of the acceptor with either the starting materials **8** or their dehydrogenation products **16** is not required. While in the work of Bryce[9] the radical anion of **3** functions as the counterion to a cation derived from an organic donor within a salt, it has in this work been covalently bonded to an α-amino radical followed by loss of cyanide. It is also noteworthy that **1** does not, to a measurable extent, act as a cyanating agent on C-1/C-3 of **8** analogously as it does in the cyanation of the cyclic amines **4a** and **4b**[5] (Scheme 1).

The cyanine-like character of compounds **15** has been pointed out earlier,[4a–c] thus **15** and as well **13** may be classified as merocyanines.[17] Two isoindole based merocyanines with *N*-phenylrhodanine as acceptor moiety have been described.[18]

5. Experimental

5.1. General

Mp's were determined with a Reichert Thermovar hot stage microscope and are uncorrected. The UV–vis spectra were recorded on a Perkin–Elmer 554 spectrometer and the IR spectra on Perkin–Elmer 397 and Bruker Vector 22 spectrometers using potassium bromide pellets; band intensities, s strong, w weak. ^{1}H 300 MHz and ^{13}C NMR 75 MHz spectra were recorded on a Bruker WM 300 instrument, 500 MHz ^{1}H and 125 MHz ^{13}C NMR spectra on a Bruker DRX 500 spectrometer. Chemical shifts are expressed as δ [ppm] with reference to tetramethylsilane as an internal standard, s=singlet, d=doublet, dd=doublet of doublets and m=multiplet. ^{13}C assignments (qC=sp^2 quaternary carbon atoms) were made with the aid of DEPT 135/90 spectra. For EI (70 eV) mass spectra Varian MAT 311 and AMD 605 instruments were used. Elemental analyses were run on a Carlo Erba 1106 CHNS analyzer. For preparative layer chromatography (plc) 1.0 mm thick air-dried layers of slurry applied silica gel Merck PF_{254} on 48 cm wide and 20 cm high glass plates were used, zones were detected by their colour and indicator fluorescence quenching upon exposure to 254 nm light and extracted with acetone.

5.2. Starting materials

2-Aryl-2,3-dihydro-1*H*-isoindoles (=2-arylisoindolines) **8a–g** and two 2*H*-isoindoles (**16c** and **16f**) were prepared

Table 3. ^{1}H chemical shifts (δ_H) of compounds **8a**,**c**,**d**,**f** and **g** (300 MHz)

8	Solvent	Isoindoline protons			*N*-Phenyl protons					Other protons	
		1-H/3-H	4-,5-,6-,7-H		2′-H	3′-H	4′-H	5′-H	6′-H		
			AA′	BB′							
a	$CDCl_3$	4.63	7.30		6.70	7.30	6.75	7.30	6.70	—	
	DMSO-d_6	4.58	7.39	7.30	6.67	7.23	6.64	7.23	6.67		
c	$CDCl_3$	4.61	7.30		6.60	7.11	—	7.11	6.60	4′-Me	2.28
	DMSO-d_6	4.54	7.38	7.30	5.75	7.05	—	7.05	5.75		2.20
d	$CDCl_3$	4.64	7.31		6.51	—	6.58	7.20	6.49	3′-Me	2.36
	DMSO-d_6	4.56	7.38	7.30	6.48s[a]	—	6.48m[a]	7.11dd	6.48m[a]		2.27
f	$CDCl_3$	4.61	7.31		6.64	6.78	—	6.78	6.64	4′-MeO	3.78
	DMSO-d_6	4.52	7.38	7.29	6.62	6.87	—	6.87	6.62		3.67
g	$CDCl_3$	4.63	7.31		6.22	—	6.32	7.21	6.32	3′-MeO	3.83

[a] Accidentally superimposed.

according to the procedures published by Kreher.[14] The ^{1}H spectral data ($CDCl_3$ as solvent) of **8a–g** were in full accord with the published data,[14] in addition, the ^{1}H NMR spectra of **8a–f** have been recorded in DMSO-d_6 (Table 3). In this solvent the AA′BB′ systems of 4-H–7-H appear as baseline separated AA′ and BB′ parts instead of narrow multiplets. ^{13}C NMR 75 MHz spectra have also been recorded (Table 4).

Compound **8a**: 2-phenyl-, mp 170–171 °C (lit.[14] 172–173 °C); *Compound* **8b**: 2-(2-methylphenyl)-, bp 118–120 °C/1.33×10^{-2} mbar (lit.[14] 117 °C/1.33×10^{-2} mbar); *Compound* **8c**: 2-(4-methylphenyl)-, mp 190–192 °C (lit.[14] 193 °C); *Compound* **8d**: 2-(3-methylphenyl)-, mp 105–106 °C (lit.[14] 111 °C); *Compound* **8e**: 2-(2-methoxyphenyl)-, bp 136–138 °C/1.33×10^{-2} mbar (lit.[14] 133–135 °C/1.33×10^{-2} mbar); *Compound* **8f**: 2-(4-methoxyphenyl)-, mp 218–220 °C (lit.[14] 219 °C); *Compound* **8g**: 2-(3-methoxyphenyl)-, mp 121–122 °C (sublimed, lit.[14] 120 °C, lit.[19] 115–117 °C).

2-(4-Methylphenyl)-2*H*-isoindole (**16c**) greyish crystals, mp 172–173 °C (lit.[14] 171 °C); 2-(4-methoxyphenyl)-2*H*-isoindole (**16f**), cream-coloured crystals, mp 174–176 °C (lit.[14] 176 °C) with rapid sublimation. Upon ice/salt cooling, the mother liquor of **16f** gave another precipitate of mp 116–123 °C (lit.[14] 114 °C), which is probably 2-(2-acetoxy-4-methoxyphenyl)-2,3-dihydro-1*H*-isoindole. Compounds **16c** and **16f** were stored at −18 °C under nitrogen.

2-(1,3-Dioxo-2,3-dihydro-1*H*-inden-2-ylidene)propanedinitrile ('dicyanomethyleneindane-1,3-dione', **1**) was prepared according to Chatterjee,[20] yellow crystals, mp 282–284 °C (with decomposition, block preheated to 260 °C, lit.[20] 280–285 °C with decomp.). IR (KBr): $\tilde{\nu}$ = 2220w(CN), 1705s (C═O) cm^{-1}. ^{1}H NMR (CD_3NO_2) 300 MHz: δ= 8.16 (AA′BB′, aryl H); ^{13}C NMR (CD_3NO_2) 75 MHz: δ=91.4 (C-2), 111.8 (CN), 126.1 (C-5′, C-6′), 139.8 (C-4′, C-7′), 143.3 (C-3a′, C-7a′), 153.5 (C-2′), 184.3 (C-1′, C-3′).

1,4-Naphthoquinone-2,3-dicarbonitrile (**3**) was prepared according to Chatterjee,[21] yellow crystals, mp 278–279 °C (with rapid sublimation and slight decomp., lit.[21] 270–271 °C, from di-chloromethane). IR (KBr): $\tilde{\nu}$ = 2235w(CN), 1676s (C═O), 1603 and 1584 cm^{-1} (aryl and C═C). ^{1}H NMR (CD_3NO_2) 300 MHz: δ=8.21 (m, AA′, 5-H, 8-H), 8.04 (m, BB′, 6-H, 7-H). ^{13}C NMR (CD_3NO_2) 75 MHz: δ=112.6 (CN), 129.0 (C-5, C-8), 131.4 (C-4a, C-8a), 132.1 (C-2, C-3), 137.6 (C-6, C-7), 178.4 (C-1, C-4).

5.3. Reactions of 2-arylisoindolines 8a–g with 1

5.3.1. General procedure. To a solution of **1** (416 mg, 2.0 mmol) in dry pyridine (15 mL) a solution of **8a–g** (1.0 mmol each) in 5 mL of pyridine was added dropwise over 5 min at room temperature with stirring and admission of air. The mixture was warmed gently to 50–60 °C and kept at this temperature with stirring and admission of air for 3 h, then warmed to max. 100 °C for few minutes and concentrated to dryness at 50 °C. The residue was taken up several times with cold ethanol (10 mL) and the slurry was concentrated again to remove any residual pyridine. The solid was then taken up in hot methanol, and the solution was filtered.

Table 4. ^{13}C chemical shifts (δ_C) of compounds **8a**,**c**,**d**,**f** and **g** (75 MHz)

8	Solvent	Isoindoline carbon atoms				*N*-Phenyl carbon atoms						Other C-signals	
		1,3	4,7	5,6	3a,7a	1′	2′	3′	4′	5′	6′		
a	$CDCl_3$	53.7	122.6	127.1	137.9	147.1	111.6	129.4	116.1	129.4	116.1	—	
	DMSO-d_6	53.5	122.8	127.3	137.8	147.2	111.9	129.3	116.1	129.3	111.9	—	
c	$CDCl_3$	53.7	122.6	127.1	138.0	145.2	111.6	129.9	125.2	129.9	111.6	4′-Me	20.3
	DMSO-d_6	53.5	122.8	127.2	138.0	145.3	111.9	129.8	124.5	129.8	111.9		20.2
d	$CDCl_3$	53.8	122.6	127.1	138.0	147.2	112.3	139.1	117.2	129.2	108.8	3′-Me	21.9
	DMSO-d_6	53.5	122.8	127.2	137.9	147.2	112.5	138.3	117.0	129.2	109.2		21.7
f	$CDCl_3$	54.3	122.5	127.1	138.3	142.2	112.4[a]	115.3	151.3	115.3	112.4	4′-OMe	56.0
	DMSO-d_6	54.0	122.8	127.2	138.2	142.1	112.7	115.1	151.1	115.1	112.7		55.6
g	$CDCl_3$	53.8	122.6	127.2	137.9	148.5	104.8	160.9	98.0	130.1	101.3	3′-OMe	55.1

[a] Broadened.

This operation was repeated four times. Filtrates and extracts were combined and concentrated to dryness and the residue was dissolved in acetone (5 mL). This solution in each case was applied to 5 plc-plates and developed with cyclohexane/ethyl acetate (4:1) for the run with **8a**, toluene/ethyl acetate (5:1) for the run with **8f**, and toluene/ethyl acetate (10:1) for all other runs. Intense blue main zones (from **8a–f**) and the purple main zone from **8g** were extracted and the residue subjected to repeated plc with the same solvents. Crystallization from acetonitrile afforded pure samples of **13a–f**, all appearing black (but tinted to some extent) with a metallic shine in incident light, but giving blue solutions in acetonitrile, ethyl acetate, chloroform or methanol. Numerous other mostly coloured zones were observed but it always contained too little material to allow for isolation of significant amounts and had to be discarded as well as the tarry materials remaining at the start line.

5.3.2. 3,3′-(2-Phenyl-2*H*-isoindol-1,3-ylene)-di-(1,4-naphthoquinone-2-carbonitrile) (13a). Black crystals, mp 331–332 °C, 139 mg (25%). IR: $\tilde{\nu}$ = 2210w (CN), 1670 and 1655 (C═O), 1585 and 1550 (aryl and C═C), 1273 cm^{-1}. ^1H NMR (CD_3NO_2) 300 MHz δ=7.22–7.36 (m, 3H, isoindolylene 6-H, 7-H and phenyl 4-H), 7.44–7.52 (m, 4H, phenyl 2-, 3-, 5-, 6-H), 7.70–7.91 (partially broadened m, 8H, isoindolylene 4-H, 7-H and 6 naphtho H), 8.12–8.19 (m, 2H, naphtho H). MS: *m/z* (%)=555 (M^+, 100), 528 (37), 502 (20), 373 (6), 347 (9), 104 (23). Anal. Calcd for $C_{36}H_{17}N_3O_4$: C, 77.83; H, 3.08; N, 7.56. Found: C, 77.84; H, 3.00; N, 7.63.

5.3.3. 3,3′-[2-(2-Methylphenyl)-2*H*-isoindol-1,3-ylene]-di-(1,4-naphthoquinone-3-carbonitrile) (13b). Black-red crystals, mp 314–315 °C, 308 mg (54%). IR: $\tilde{\nu}$ = 2210 (CN), 1675 and 1660 (C═O), 1585 and 1540 (aryl, C═C), 1270 cm^{-1}. ^1H NMR (CD_3NO_2, 297 K) 300 MHz δ=2.20 (s, 3H, CH_3), 7.05–7.20 (m, 2H, isoindolylene 5-H, 6-H), 7.35–7.65 (m, 4H, phenyl 3-, 4-, 5-, 6-H), 7.70–7.95 (m, 8H, isoindolylene 4-H, 7-H and 6 naphtho-H), 8.00–8.25 (m, 2H, naphtho H). (DMF-d_7, 343 K): δ=2.26 (broadened, 3H, CH_3), 7.15 (m, 3H, isoindolylene 5-H, 6-H and 1 phenyl H), 7.45 (m, 2H, phenyl H), 7.51 (m, 1H, phenyl H), 7.74 (broadened, 2H, isoindolylene 4-H, 7-H), 7.79–8.05 (m, 6H, naphtho H) and 8.12 (m, 2H, naphtho H). ^{13}C NMR (DMF-d_7, 343 K) 75 MHz δ=18.02 (CH_3); signals for sp^2 *C*H (for 2C each) at 121.9, 126.0, 127.0, 127.3, 135.4, 135.5 and for 1C each at 126.8, 129.9, 131.0 and 131.9 (all phenyl); signals for qC (all broadened, 2 qC each) at 132.2 (C-3a, C-7a), 132.7, 136.7, 137.9, weak and broadened signals at 179 and 181 (C═O), two signals for 2qC each and two signals for 1qC each could not be determined, also CN resonances were not detected. MS: *m/z* (%)=569 (M^+, 100), 554 (8), 543 (16), 517 (4), 399 (7), 387 (55), 361 (7), 284 (7), 104 (23), 76 (31). Anal.: See below.

5.3.4. 3,3′-[2-(4-Methylphenyl)-2*H*-isoindol-1,3-ylene]-di-(1,4-naphthoquinone-2-carbonitrile) (13c). Black-red crystals, mp 321–323 °C, 239 mg (42%). IR: $\tilde{\nu}$ = 2210w (CN), 1670–1650 (C═O), 1590 and 1540 (aryl and C═C), 1270 cm^{-1}; ^1H NMR (CD_3NO_2) 300 MHz δ=2.20 (s, 3H, CH_3), 7.05–7.18 (m, 2H, isoindolylene 5-H, 6-H), 7.28–7.55 (m, 4H, 2-, 3-, 5-, 6-H), 7.70–8.00 (partly broadened m, 8H, isoindolylene 5-H and 6-H and 6 naphtho H), 8.10–8.20 (m, 2H, naphtho H). MS: *m/z* (%)=569 (100, M^+), 554 (4), 543 (22), 517 (13), 486 (8), 361 (21), 284 (10), 104 (14), 76 (42). Anal.: See below.

5.3.5. 3,3′-[2-(3-Methylphenyl)-2*H*-isoindol-1,3-ylene]-di-(1,4-naphthoquinone-2-carbonitrile) (13d). Black crystals, mp 282–283 °C, 182 mg (32%). IR: $\tilde{\nu}$ = 2210w (CN), 1680–1665 and 1650 (C═O), 1580 and 1530 (aryl and C═C), 1270 cm^{-1}. ^1H NMR (CD_3NO_2) 300 MHz δ=2.15 (s, 3H, CH_3), 7.08–7.55 (series of 5 mostly broadened m, 8H, isoindolylene 4-, 5-, 6-, 7-H and phenyl 2-, 4-, 5-, 6-H), 7.66–7.92 (partially broadened m, 6H, naphtho H), 8.16–8.20 (m, 2H, naphtho H). MS: *m/z* (%)=569 (100, M^+), 554 (5), 543 (29), 517 (13), 387 (8), 361 (24), 104 (83), 76 (44). Anal. Calcd for $C_{37}H_{19}N_3O_4$: C, 78.02; H, 3.36; N, 7.37. Found: **13b**: C, 77.94; H, 3.33; N, 7.50. **13c**: C, 77.83; H, 3.22; N, 7.48. **13d**: C, 77.88; H, 3.35; N, 7.29.

5.3.6. 3,3′-[2-(2-Methoxyphenyl)-2*H*-isoindol-1,3-ylene]-di-(1,4-naphthoquinone-2-carbonitrile) (13e). Purple-black crystals, mp 327–328 °C, 357 mg (61%). IR: $\tilde{\nu}$ = 2210w (CN), 1665–1650 (C═O), 1585–1545 (aryl and C═O), 1270 cm^{-1}. ^1H NMR (CD_3NO_2) 300 MHz δ=3.75 (s, 3H, OCH_3), series of 4 sharp lined m at 6.75–7.30 (3H, isoindolylene 5-H, 6-H and 1 phenyl H), 7.31–7.55 (3H, phenyl H), 7.65–8.00 (8H, isoindolylene 4-H, 7-H and 6 naphtho H), 8.05–8.25 (2H, naphtho H). MS: *m/z* (%)=585 (100, M^+), 570 (7), 554(9), 528 (9), 502 (4), 403 (22), 389 (13), 76 (33). Anal.: See below.

5.3.7. 3,3′-[2-(4-Methoxyphenyl)-2*H*-isoindol-1,3-ylene]-di-(1,4-naphthoquinone-2-carbonitrile) (13f). Black-red crystals, mp 337–338 °C, 275 mg (47%). IR: $\tilde{\nu}$ = 2210w (CN), 1670–1660 and 1645 (C═O), 1590, 1530 and 1503 (aryl and C═C), 1272 cm^{-1}. ^1H NMR (CD_3NO_2) 300 MHz δ=3.68 (s, 3H, OCH_3), 6.74–6.95 (m, 2H isoindolylene 5-H, 6-H), 7.30–7.58 (m, 4H, phenyl H), 7.70–8.00 (m, 8H, isoindolylene 4-H, 7-H and 6 naphtho H), 8.10–8.28 (m, 2H, naphtho H). ^1H NMR (DMF-d_7, 297 K) 500 MHz δ=3.68 (s, 3H, OCH_3), 6.89 (m, 2H, isoindolylene 5-H, 6-H), 7.47 (m, 2H, phenyl 3-, 5-H); the following low-field signals for isoindolylene and naphtho H were all structureless and broadened: 7.66 (3H), 7.80–8.10 (7H), 8.17 (2H). ^1H NMR (DMF-d_7, 343 K) 500 MHz δ=3.68 (s, 3H, OCH_3), 6.88 (m, 2H, isoindolylene 5-H, 6-H), 7.41 (dd, *J*=9.0 and 2.5 Hz, 2H, phenyl 3-H, 5-H), all other signals were broadened and structureless: 7.51 (2H, phenyl 2-H, 6-H), 7.70 (2H, isoindolylene 4-H, 7-H); the naphthoquinonyl H gave multiplets at 7.82 (2H), 7.92 (4H) and 8.13 (2H). ^{13}C NMR (DMF-d_7, 297 K) 125 MHz δ=55.9 (OCH_3); sharp sp^2 *C*H resonances (for 2C each) at 115.5, 121.9, 125.7 and as broadened signals for 2C each: 126.9, 127.2, 129.1, 135.3, 135.6; several unresolved resonances for qC at 132.1–133.5, 160.0 (C═O, only one signal observed), no CN signals. (DMF-d_7, 343 K): δ=55.9 (OCH_3), sp^2 *C*H signals (for 2C each) at 115.6, 121.8, 125.8, 127.0, 127.3, 129.5 (broadened), 135.4, 135.5; several broad unresolved signals for qC at 132.0–133.5, 160.4 (C═O, only one signal observed), no CN signals. MS: *m/z* (%)=585 (100, M^+), 570 (5), 543 (20), 528 (13), 502 (3), 403 (8), 104 (38), 76 (35). Anal. Calcd for $C_{37}H_{19}N_3O_5$: C, 75.89; H, 3.27; N, 7.17. Found: **13e**: C, 75.70; H, 3.00, N, 713. **13f**: C, 75.91; H, 3.22; N, 7.19.

5.3.8. [4-(2,3-Dihydro-1*H*-isoindol-2-yl)-2-methoxyphenyl]-(1,3-dioxoindan-2-ylidene)-acetonitrile (15). This substance is characterized on the solvent moist plc-plate by a purple zone, which changes to grey-violet on drying. Black to blue-violet crystals (from ethanol), mp 224–226 °C, 154 mg (38%). Vis (methanol): λ_{max}=560 nm, log ε=4.1. IR: $\tilde{\nu}$ = 2230−2220 (CN), 1675s (C═O), 1616, 1590, 1530 and 1505 cm^{-1} (aryl, C═C). ^1H NMR ($CDCl_3$, ambient temp) 300 MHz δ=3.91 (s, 3H, OCH_3), 4.81 (s, 4H, CH_2), 6.14 (d, J=2.2 Hz, 1H, phenyl 2-H), 6.37 (dd, J=8.8 and 2.2 Hz, 1H, phenyl 6-H), 7.30 (m, 4H, isoindolinyl aryl H), 7.54 (d, J=8.8 Hz, 1H, phenyl 5-H), 7.63–8.08 (m, 4H, dione aryl H). ^1H NMR (CD_3NO_2, 297 K) 500 MHz δ=3.97 (s, 3H, OCH_3), 4.88 (s, 4H, CH_2), 6.36 (d, J=2.3 Hz, 1H, phenyl-2H), 6.49 (dd, J=8.8 and 2.3 Hz, 1H, phenyl 6-H), 7.38 (m, 2H) and 7.46 (m, 2H, isoindoline aryl H), 7.52 (d, J=8.9 Hz, 1H, phenyl 5-H), 7.89–8.12 (broadened, several m, 4H, dione aryl H). ^{13}C NMR (CD_3NO_2, 297 K) 125 MHz δ=55.2 ($2CH_2$), 56.5 (OCH_3), sp^2 *C*H signals at 95.7 (phenyl C-2), 106.3 (phenyl C-6), 111.6 (CN), 124.1 (isoindolinyl C-5, C-6), 129.0 (isoindolinyl C-4, C-7), 137.0 and 137.1; qC at 138.4 (isoindolinyl C-3a, C-7a), 117.7, 123.3, 133.4, 142.1, 143.0, 154.6, 163.2, 188.1 (C═O), 189.0 (C═O). MS: *m*/*z* (%)=406 (11, M^+), 380 (70), 349 (2), 224 (100), 209 (24), 193 (11), 179 (43). Anal. Calcd for $C_{26}H_{18}N_2O_3$: C, 76.83; H, 4.46; N, 6.89. Found: C, 76.68; H, 4.53; N, 7.19.

5.3.9. Semi-micro-scale conversions.

5.3.9.1. With isoindolines 8f and 8g. Samples (11 mg, 0.05 mmol) each of **8f** and **8g**, respectively, in 0.5 mL of pyridine were added to solutions (1 mL) of 31 mg (0.15 mmol) of **1** and **3**, respectively, in the same solvent (runs A–D). The mixtures were kept under otherwise the same conditions as used in the preparative scale runs (gentle warming up to 50 °C, 3 h at this temperature with admission of air). After concentration to dryness the residues were examined by tlc. Significant spots were identified by comparison with and admixing of authentical samples. A (**8f+1**): First light green, than deep green colouration, later greyish blue, compound **13f** definitively present. B (**8f+3**): Deep red-brown colouration, later brown. Compound **13f** definitively absent (3 repetitions). C (**8g+1**): Dark olive green colouration, spot of **15** dominating. D (**8g+1**): Dark brown, compound **15** definitively absent, some minor coloured zones detectable.

5.3.9.2. With 2*H*-isoindoles 16c and 16f. Samples 0.05 mmol each of **16c** and **16f**, respectively, in 0.5 mL of pyridine were treated as described above with solutions of **1** and **3** (0.1 mmol each) in pyridine, and the reaction residues were examined by tlc. The definite absence of products **13c** and **13f**, respectively, in the reaction both with **1** and **3** was corroborated by parallel chromatography and addition of authentic samples.

5.4. Single crystal X-ray structure determination of 13f

Suitable crystals were obtained by recrystallization from acetonitrile. Data were recorded using an Enraf–Nonius Kappa CCD diffractometer with graphite-monochromated Mo K_α-radiation (λ=0.71073 Å). The crystal was mounted in a stream of cold nitrogen gas. The structure was solved by direct methods (*SHELXS-97*[22]) and refined by full matrix least squares techniques against F^2 (*SHELXL-97*[23]). Hydrogen atoms were inserted from geometry consideration using the HFIX option of the program.

Crystal data. $C_{37}H_{19}N_3O_5$, M_r=585.55 g mol^{-1}, dark red, crystal size 0.43×0.34×0.12 mm^3, monoclinic, $P2_1/n$, [no. 14], a=15.83020(10) Å, b=10.91510(10) Å, c=16.62470(10) Å, β=103.65(3)°, V=2791.38(4) $Å^3$, D_{calc}=1.393 Mg m^{-3}, μ=0.094 mm^{-1}, T=100 K, λ=0.71073 Å, θ range for data collection 2.25–33.22°, 94943 reflections collected, 10676 independent reflections, 9362 reflections with $I>2\sigma(I)$; Gaussian absorption correction, max. 0.99/min. 0.95, 482 parameters, S=1.439, R_1=0.0504, wR^2=0.1803, largest difference max. and min. 0.9/−0.9 e$Å^{-3}$.

Crystallographic data (excluding structure factors) have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication number CCDC 615812. Copies of the data can be obtained, free of charge, on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: +44 1223 336033 or e-mail: deposit@ccdc.cam.ac.uk).

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