Acetylenic Quinoxalinoporphyrazines as Photosensitisers for Photodynamic Therapy

Frieder Mitzel,[a, b] Simon FitzGerald,[c] Andrew Beeby,[c] and Rüdiger Faust*[a]

Abstract: A range of lipo- and hydrophilic derivatives of the new class of octaalkynyl tetra-[6,7]-quinoxalinoporphyrazines (TQuiPors), analogues of the naphthalocyanines, were prepared in two steps starting from functionalised hexa-1,5-diyne-3,4-diones. Divalent zinc and magnesium ions were introduced into the macrocyclic core. Whereas the triisopropylsilyl-, 3,5-di-*tert*-butylphenyl- and 4-triisopropylsilyloxyphenyl-terminated acetylenic TQuiPors are lipophilic and hence soluble in standard organic solvents, a polyethylene glycol-substituted derivative was found to dissolve in DMSO as well as in ethanol/water mixtures. The new chromophores are characterised by intense UV/Vis/NIR absorptions, most notably by bands at 770 nm with extinction coefficients exceeding 500 000 $M^{-1}cm^{-1}$. With a view to possible photodynamic therapy applications, the potency of the chromophores to sensitise the formation of singlet oxygen was examined, both qualitatively using a 1,3-diphenylisobenzofuran assay, and quantitatively by the determination of the singlet oxygen quantum yields. It was found that all TQuiPors produce singlet oxygen when irradiated in the presence of air. In particular, the octaalkynyl Zn-TQuiPor generates singlet oxygen with a quantum yield of 56%, thereby rivalling, and, in conjunction with its absorption profile, even exceeding the standards set by established PDT agents. The photostabilities of the TQuiPors were assessed and generally found to be satisfactory, but dependent on the solvent and the wavelength of the incident light.

Keywords: alkynes · photodynamic therapy · photooxidation · phthalocyanines · singlet oxygen

Introduction

Photodynamic therapy (PDT) is defined as the combined action of a photosensitiser, light and molecular oxygen to generate reactive oxygen species, notably singlet oxygen, which then reacts with biomolecules to treat certain medical conditions.[1, 2] The most prominent PDT application arguably lies in the treatment of various forms of cancer, in particular those of hollow organs (colon, oesophagus, etc.) and the skin.[3–7] Increasingly, however, the principles of PDT are also used to battle other diseases, among them age-related macular degeneration,[8] the major cause for blindness in the elderly, and arteriosclerosis.[9–11] In addition, PDT is at the centre of new developments in areas such as gene therapy[12] and blood sterilisation.[13]

The successful realisation of any PDT concept crucially depends on the nature of the photosensitiser,[14] whose efficiency is determined among other things by its (bio-)availability, its potency as a singlet oxygen producer and its accessibility by external light in a biological matrix. While the sensitiser's bioavailability in the target tissue can be optimised by adjusting its solubility profile, the photophysical requirements define an optical window for sensitiser excitation between 600 and 800 nm. Due to the enhanced light penetration of biological tissue at longer wavelengths chromophores with absorbances at the low-energy end of this region are preferred (Figure 1). Most clinical efforts currently focus on porphyrin-based sensitisers such as the haematoporphyrin **1** (commercialised as a mixture of porphyrins under the brand name Photofrin),[7] the protoporphyrin prodrug 5-aminolaevulinic acid (e.g. Levulan)[15, 16] and *meso*-tetrakis(*m*-hydroxyphenyl)chlorin **2** (Foscan)[17–19] despite their low-intensity absorbance maxima around 630 and 650 nm (Figure 1). To address this point phthalocyanines (e.g. **3**),[20] porphyrin isomers such as the porphycenes[22–24] and expanded porphyrins[21] such as the texaphyrins (e.g. **4**)[25–27] have been developed and are currently being tested for PDT applications.

We have contributed to this area by designing phthalocyanines and phthalocyanine analogues with peripheral acetylene substitution.[28–30] These chromophores not only benefit from

[a] Dr. R. Faust, Dr. F. Mitzel
Christopher-Ingold-Laboratories
Department of Chemistry
University College London
20 Gordon Street, London WC1H 0AJ (UK)
E-mail: r.faust@ucl.ac.uk

[b] Dr. F. Mitzel
Laboratorium für Organische Chemie
ETH Zürich, Hönggerberg HCI G306
Wolfgang-Pauli-Strasse 10
8093 Zürich (Switzerland)

[c] Dr. A. Beeby, Dr. S. FitzGerald
Department of Chemistry
South Road
Durham DH1 3LE (UK)

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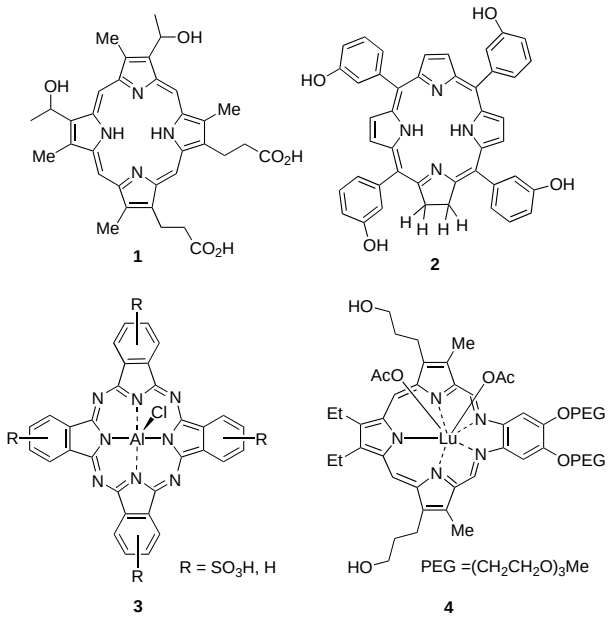
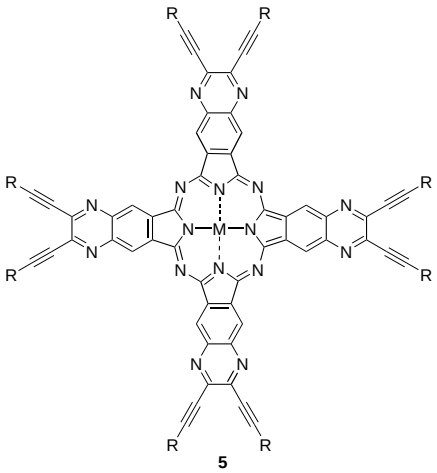


Figure 1. PDT photosensitisers currently in use or in clinical development.

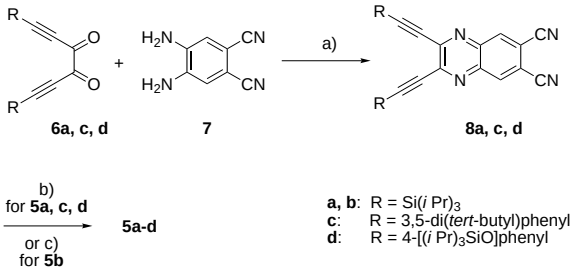
an expanded π-system and the associated batho- and hyperchromically shifted absorption profile in comparison to non-alkynylated congeners, but, in addition, offer a convenient handle to modulate their solubility properties by varying the terminal acetylene substituents. We present here an example of the versatility of this approach and describe the synthesis of lipo- and hydrophilic octaalkynyltetra-[6,7]-quinoxalinoporphyrazines **5**. These systems are characterised by intense absorptions around 770 nm and efficiently produce singlet oxygen in the presence of light and air. As far as we are aware, the tetra-[6,7]-quinoxalinoporphyrazines **5**, structural isomers of the known tetra-[2,3]-quinoxalinoporphyrazines,[31, 32] are the first members of a new class of phthalocyanine-based chromophores,[33] which we aim to develop into viable PDT agents. A preliminary communication describing our first efforts towards this goal has appeared.[34]



5a: M = Mg, R = Si(*i* Pr)$_3$
5b: M = Zn, R = Si(*i* Pr)$_3$
5c: M = Mg, R = 3,5-di(*tert*-butyl)phenyl
5d: M = Mg, R = 4-[(*i* Pr)$_3$SiO]phenyl
5e: M = Mg, R = 2,6-Me$_2$-4-PEGO-phenyl

Results and Discussion

Synthesis: The backbone of the tetra-[6,7]-quinoxalinoporphyrazines, octaaza-analogues of the naphthalocyanines, is conveniently assembled by a base-induced cyclotetramerisation of dicyanoquinoxalines, which in turn are obtained from the condensation of 1,2-diones with 1,2-diamino-4,5-dicyanobenzene (Scheme 1). This short, two-step protocol ensures a high degree of synthetic flexibility, as porphyrazine construction is limited only by the availability of suitably functionalised diketones. Peripheral acetylene substitution of the target chromophores can therefore be achieved starting from the corresponding acetylenic 1,2-diones, namely the hexa-1,5-diyne-3,4-diones **6**. We have earlier developed the copper-mediated two-fold alkynylation of oxalyl chloride[35] as a route to these diacetylenic building blocks and have prepared diones **6a**[35] and **6c**.[29] The second building block, 1,2-diamino-4,5-dicyanobenzene (**7**), is described with conflicting analytical data in the literature,[36] and was prepared for this work by the reaction of 1,2-diamino-4,5-dibromobenzene[37, 38] with CuCN in DMF. Hence, condensation of **6a** and **6c**, respectively, with **7** in acetic acid at room temperature afforded the dicyanoquinoxalines **8a** and **8c** as crystalline solids that can be easily purified by recrystallisation (Scheme 1). The base-induced cyclotetramerisation of **8a** and **8c** using magnesium butanolate in refluxing butanol generated, with **5a** and **5c**, the first (lipophilic) members of the class of the tetra-[6,7]-quinoxalinoporphyrazines. The introduction of Zn^{2+} into the central core of the porphyrazines as in **5b** succeeds by the cyclotetramerisation of the dicyanoquinoxaline **8a** with LiOPent in refluxing pentanol[39, 40] and the subsequent addition of Zn(OAc)$_2$.



Scheme 1. Synthesis of octaalkynyltetra-[6,7]-quinoxalinoporphyrazines **5a–d**. a) AcOH, room temp. **8a**: 66%, **8c**: 75%, **8d**: 80%. b) Mg(OBu)$_2$, BuOH, reflux. **5a**: 43%, **5c**: 29%, **5d**: 35%. c) LiOPent, PentOH, reflux, then Zn(OAc)$_2$. **5b**: 39%.

In order to access more hydrophilic derivatives of **5** the introduction of hydroxyl groups at the aryl termini of the acetylenes of **5** was explored. As a first example, we prepared the silyloxyphenyl-terminated dione **6d** along the route depicted in Scheme 2 starting from commercially available 4-iodophenol **9**. Thus, conversion of **9** into its corresponding triisopropysilyl ether **10** was followed by the alkynylation of **10** with 2-methylbut-3-yn-2-ol under Sonogashira conditions.[41, 42] Subsequent liberation of the terminally free acetylene **11** was achieved using potassium hydroxide in refluxing benzene. The arylacetylene **11** was then converted to

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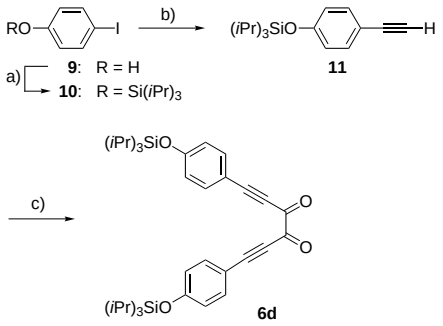
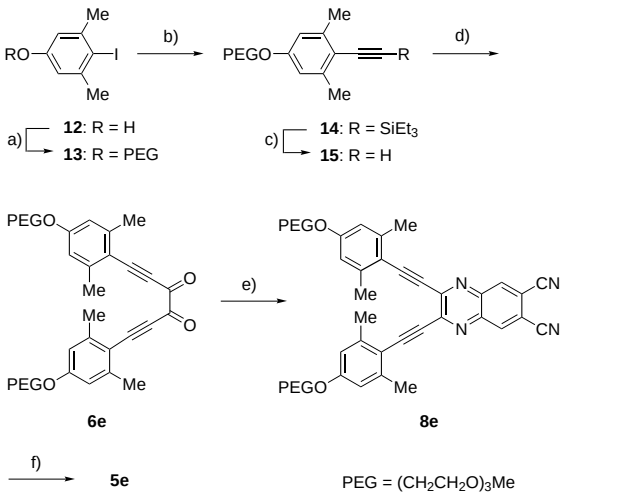


Scheme 2. Synthesis of dialkynyl-1,2-dione **6d**. a) $(i\mathrm{Pr})_3\mathrm{SiCl}$, imidazole, CH_2Cl_2, RT, 14 h, 93%. b) 1) 2-Methylbut-3-yn-ol, $[PdCl_2(PPh_3)_2]$, CuI, PhMe, Et_3N, RT, 30 min; 2) PhH, KOH, reflux, 3 h, 68%. c) 1) BuLi; 2) LiBr, CuBr; 3) $(COCl)_2$, THF, 0 °C, 15 min, 46%.



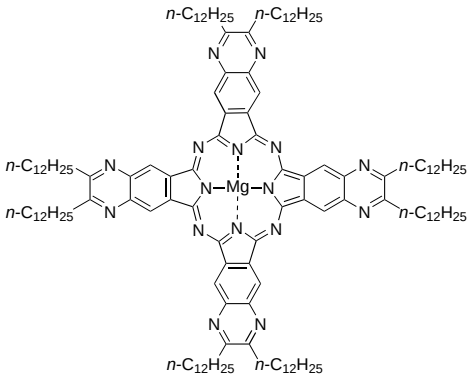
Scheme 3. Synthesis of PEGylated octaalkynyltetra-[6,7]-quinoxalinoporphyrazine **5e**. a) 2-[(methoxyethoxy)ethoxy]ethyl bromide, K_2CO_3, CH_3CN, reflux, 15 h, 75%. b) $Et_3SiC{\equiv}CH$, $[PdCl_2(PPh_3)_2]$, CuI, Et_3N, reflux, 2 h, 83%. c) Bu_4NF, moist THF, RT, 15 min, 100%. d) 1) BuLi; 2) LiBr, CuBr; 3) $(COCl)_2$, THF, 0 °C, 15 min, 40%. e) **7**, AcOH, RT, 20 min, 85%. f) $Mg(OBu)_2$, BuOH, reflux, 1.5 h, 18%.

dione **6d** using the copper-mediated alkynylation of oxalyl chloride. Finally, **6d** was converted via quinoxaline **8d** to the corresponding quinoxalinoporphyrazine **5d** using the protocol outlined in Scheme 1.

Although siloxyphenyl-substituted quinoxalinoporphyrazine **5d** continues to be a lipophilic chromophore, it was expected that the solubility of **5d** could be modified by exploring the chemistry of the latent phenolate groups. However, attempted desilylations using tetrabutylammonium fluoride at either the dione or the dicyanoquinoxaline stage were ill-fated as the phenolate intermediates generated proved to be exceedingly unstable and decomposed rapidly. The chemical manipulation of **5d** itself was deemed unpractical as the conversion of eight functional groups at a time would result in low yields and/or complex reaction mixtures. Moreover, a putative protodesilylated derivative of **5d** was expected to be quite insoluble.[43]

The strategy to obtain hydrophilic derivatives of **5** was therefore slightly adjusted and, in analogy to texaphyrin **4**, solubilising polyethyleneglycol (PEG) chains were implemented on the aryl-termini of the dialkynyl-1,2-diones (Scheme 3). In a further structural modification the aryl acetylene moiety was equipped with two methyl groups flanking the CC triple bonds. This substitution pattern was thought to enforce a porphyrazine conformation in which the planes of the aryl groups of two vicinal arylethynyl units are perpendicular to that of the main chromophore. The methyl substituents will thus protrude above and below that plane and should at least diminish chromophore aggregation.[43] Hence, the reaction of 4-iodo-3,5-dimethylphenol (**12**)[44] with 2-[(methoxyethoxy)ethoxy]ethyl bromide[45] in the presence of potassium carbonate afforded aryl iodide **13** which was alkynylated with triethylsilylacetylene under Sonogashira conditions to give **14**. Protodesilylation of **14** with tetrabutylammonium fluoride afforded the free terminal acetylene **15** which was converted to dialkynyl-1,2-dione **6e** using the copper-mediated alkynylation of oxalyl chloride. Condensation of **6e** with 1,2-diamino-4,5-dicyanobenzene **7** led to the dicyanoquinoxaline **8e**, and subsequent cyclotetramerisation yielded the corresponding octaalkynyltetra-[6,7]-quinoxalinoporphyrazine **5e**.

For comparison purposes, the alkyl-substituted derivative **16** was prepared by the route depicted in Scheme 1 starting from hexacosa-13,14-dione[46] via the corresponding quinoxaline **17**.



The octaalkynyltetra-[6,7]-quinoxalinoporphyrazines are deep blue (**5a**, **b**) or dark green (**5c**, **d**) solids with the exception of green, waxy **5e**. All chromophores are soluble in common organic solvents (CH_2Cl_2, $CHCl_3$, THF, Et_2O, EtOAc) and are easily purified by chromatography on silica gel and subsequent gel permeation chromatography on cross-linked polystyrene (eluting with THF). Gratifyingly, PEGylated **5e** shows appreciable solubility in methanol, ethanol, ethanol/water mixtures (up to 1:1 *v*/*v*) and DMSO, which represent typical formulation systems currently in use with other PDT-active chromophores.[1] More lipophilic PDT agents are commonly administered using colloidal delivery systems such as liposomes.[47, 48]

Photophysical properties: The absorption profiles of the new acetylenic chromophores are of particular interest, as this parameter serves as a first measure by which to gauge the potential of the compounds in future PDT applications. As

with other typical phthalocyanine-type chromophores, the spectra of the tetra-[6,7]-quinoxalinoporphyrazines **5** and **16** are dominated by a higher-energy B-band (around 400 nm) and a lower-energy Q-band (around 750 nm) (Figure 2, Table 1), both of which are characterised by high extinction coefficients. For example, the absorption spectrum of silylethynyl-derivative **5a** at room temperature in THF features a

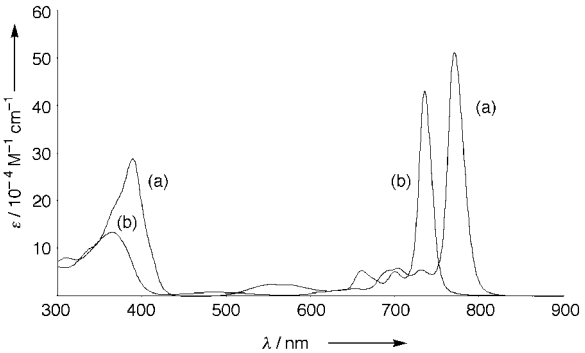


Figure 2. UV/Vis/NIR-spectra of **5a** (a) and **16** (b) in THF at room temperature.

Table 1. UV/Vis/NIR-absorption maxima of tetra-[6,7]-quinoxalinoporphyrazines.[a]

	B-band/ nm (ε/M^{-1} cm^{-1})	Q-band/ nm (ε/M^{-1} cm^{-1})
5a	389 (288000)	771 (510700)
5b	380 (249000)	770 (507000)
5c	394 (305500)	770 (516800)
5d	397 (264000)	772 (411000)
5e[b]	397 (172000)	774 (233200)
16	364 (133100)	735 (431000)

[a] All measurements in THF at RT. [b] B- and Q-band values in DMSO at RT: 400 nm (140400 M^{-1} cm^{-1}), 787 nm (38500 M^{-1} cm^{-1}).

B-band at 389 nm ($\varepsilon = 288000$ M^{-1} cm^{-1}) and a Q-band at 771 nm ($\varepsilon = 510000$ M^{-1} cm^{-1}). A comparison between the UV/Vis/NIR spectra of alkyl-substituted **16** and triisopropylsilyl-substituted **5a** (Figure 2) reveals that the introduction of eight acetylene groups leads to bathochromically and hyperchromically shifted absorption maxima of both, the B- and the Q-band. As the long wavelength maxima of all acetylenic chromophores **5** peak beyond the visible at around 770 nm, their absorption profile is ideally suited for addressing these compounds in a biological environment and for efficient singlet oxygen generation. It is interesting to note in this context that the PDT-relevant absorption maxima of haematoporphyrin **1** and texaphyrin **4**, established PDT agents of the first and the second generation, are at 630 nm ($\varepsilon = 5000$ M^{-1} cm^{-1}) and 732 nm ($\varepsilon = 42000$ M^{-1} cm^{-1}), respectively.[1]

There is virtually no difference in the Q-band positions of the silyl-terminated octaalkynylquinoxalinoporphyrazines **5a**,**b** on one hand and the aryl-terminated porphyrazines **5c** and **5d**; this, however, suggests that the chromophores' effective π-systems do not extend to the peripheral phenyl rings. The aryl substituents can therefore be used to fine-tune the compound's pharmacological profile without, principally, affecting their beneficial optical properties. However, the notable drop in the B- and Q-band intensities of **5d** and freshly prepared solutions of **5e** in particular, points to an increasing aggregation of these large aromatic macrocycles, a behaviour that also prevented the accumulation of NMR data for these compounds. It is therefore clear that any further structural variations on **5** need to consider the impact of such hydrophobic effects on these systems. All tetra-[6,7]-quinoxalinoporphyrazines are fluorescent, showing small Stokes shifts of about 20 nm upon excitation at wavelengths corresponding to either their B- or Q-bands.

Singlet oxygen generation and photostability: The potential of the quinoxalinoporphyrazines to induce photooxidation was first established qualitatively using the oxidative degradation of 1,3-diphenylisobenzofuran (DPBF). This established singlet oxygen quencher undergoes a cycloaddition reaction with $^1O_2$ to produce an endoperoxide which, in protic solvents, converts swiftly to 1,2-dibenzoylbenzene.[49, 50] The photooxidative degradation of DPBF can be monitored using its absorption maximum at 413 nm, a region in which 1,2-dibenzoylbenzene does not show any absorption. Figure 3 illustrates the outcome of one such experiment. Hexanol solutions of DPBF and sensitisers were prepared such that the absorption at 413 nm was approximately $A = 1$. The concentration of the photosensitiser was $[PS] = 5.0 \times 10^{-7}$ M in each experiment. The time-dependent absorption at 413 nm was monitored while the solutions were irradiated in quartz cuvettes at room temperature using an ordinary slide-projector halogen lamp (24 V, 250 W) with a fluence rate of 50 mW cm^{-1}. High-energy wavelengths (< 550 nm) were filtered out by passing the incident beam through an appropriate cut-off filter. As can be seen from Figure 3, the DPBF absorption maximum at 413 nm decays exponentially in the presence of photosensitiser **5b**, air and light (trace d). Control experiments reveal that the presence of the quinoxalinoporphyrazine sensitisers is essential for an oxidative DPBF degradation (trace b). However, some degree of photobleaching, that is DPBF decay in the absence of oxygen, is also observed (trace c). Similar profiles were obtained for

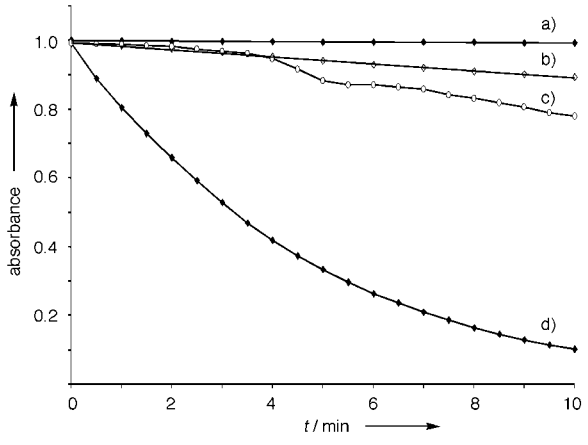


Figure 3. Photooxidation of 1,3-diphenylisobenzofuran (DPBF) with **5b** in aerated hexanol at room temperature (d). The DPBF absorption at 413 nm was monitored. a) In the absence of light; b) in the absence of **5b**; c) in the absence of oxygen.

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5a, although in this case the rate of DPBF degradation was somewhat slower. The PEGylated derivative **5e**, however, showed little photooxidising potential in the qualitative assay with DPBF–a finding that we attribute to the high degree of aggregation of **5e** in this solvent. In contrast, quinoxalinoporphyrazines **5a** and **5b** show little aggregation at this concentration range in hexanol.

The efficiency with which the tetra-[6,7]-quinoxalinoporphyrazines can generate singlet oxygen was also assessed quantitatively by determining their singlet oxygen quantum yields using $^1O_2$-phosphorescence measurements in THF (Table 2). The results of these experiments reveal notable differences. Compared with the non-acetylenic reference compound **16** ($\Phi_\Delta = 0.15$), all acetylenic tetra-[6,7]-quinoxalinoporphyrazines sensitise the formation of singlet oxygen more efficiently, albeit to various degrees. Whereas the singlet oxygen quantum yield Φ_Δ of Mg-coordinated **5a** amounts to only 0.19, that of PEGylated **5e** is increased to 0.37, and is surpassed by that of Zn-derivative **5b** with a Φ_Δ value of 0.56. The superiority of Zn^{2+} coordinated to the macrocyclic core of phthalocyanine-type photosensitisers in inducing singlet oxygen has been noted before and is attributed to their high triplet quantum yields and their long triplet state lifetimes.[14] The values obtained for **5b** and **5e** compare favourably with the singlet oxygen quantum yields of other sensitisers currently in use in photodynamic therapy (e.g. protoporphyrin: $\Phi_\Delta = 0.57$ in benzene; texaphyrin **4**: $\Phi_\Delta = 0.11$ in MeOH).[1]

Table 2. Fluorescence lifetimes τ_f, fluorescence quantum yields Φ_f, and singlet oxygen quantum yields Φ_Δ for selected tetra-[6,7]-quinoxalinoporphyrazines.[a]

	τ_f/ns	Φ_f[b]	Φ_Δ[c]
5a	4.3 ± 0.1	0.46	0.19
5b	2.4 ± 0.1	0.25	0.56
5e	4.0 ± 0.1	0.43	0.37[d]
16	5.3 ± 0.1	0.59	0.15

[a] All measurements in aerated THF at RT. [b] Absolute values (±10%) relative to cresyl violet in MeOH ($\Phi_f = 0.54$) and disulfonated phthalocyanine standards in H_2O ($\Phi_f = 0.40$) standards. [c] Obtained by time-resolved phosphorescence measurements using excitation at $\lambda_{ex} = 355$ nm. Values are relative to perinaphthenone ($\Phi_\Delta = 0.97$) and have an error of ±10%. [d] Due to photodegradation we estimate the error margin to be ca. ±20%.

We have also examined the photostability of the novel tetraquinoxalinoporphyrazines **5** by irradiating aerated hexanol solutions under conditions identical to those described for the DPBF experiments (slide projector halogen lamp: 24 V, 250 W, fluence rate: 50 mW cm^{-1}, cut-off filter < 550 nm) and by monitoring the Q-band absorption of the chromophore. Sensitisers **5b** and **5e** display remarkable photostabilities (less than 6% degradation after irradiation for 4 h). In contrast, porphyrazine **5a** is less photostable under these conditions and undergoes 45% photodegradation within four hours. The situation is quite different when an aerated THF solution of **5e** is irradiated at 355 nm in the spectrofluorimeter. In this case, complete chromophore degradation occurs within 7 min to yield an unspecified photoproduct with a fluorescence at 500 nm. Efforts to elucidate the nature of the photodegradation product of **5e** by mass spectrometry were unsuccessful, but the loss of the original emission at 790 nm points to the disrupture of the macrocyclic porphyrazine framework of **5e**. Interestingly, derivatives **5a–d** are photostable under these conditions. It appears that the higher photostability of **5e** in hexanol as compared to THF is a result of chromophore aggregation in the former solvent whereas in the latter the reduced degree of aggregation seems to facilitate photo-induced decomposition. However, we have currently no satisfying explanation for the differing photostabilities of **5e** and **5a–d** in THF, a solvent in which all quinoxalinoporphyrazines prevail in non-aggregated form at the concentrations used.[51]

Conclusion

We have devised a flexible and concise synthetic route to a new class of photosensitiser, the octaalkynyltetra-[6,7]-quinoxalinoporphyrazines **5**. Starting from appropriately functionalised dialkynyl-1,2-diones lipophilic and hydrophilic derivatives of these chromophores are readily prepared. The title compounds feature intense absorptions in the near infrared, efficiently photosensitise the generation of singlet oxygen and, with the exception of the more hydrophilic derivative **5e**, possess satisfactory photostability. Based on the flexibility of our approach, an elaboration of these systems into bioavailable, target-specific PDT agents seems therefore warranted and work towards this goal is currently underway.

Experimental Section

General: All reactions were conducted in oven-dried glassware under an argon atmosphere. Unless otherwise indicated, all reagents were purchased from commercial suppliers and were used as received. Known starting materials that were not commercially available were prepared according to literature procedures cited in the text. Solvents were purified and dried according to customary procedures:[52] THF was distilled from sodium/benzophenone under a nitrogen atmosphere; toluene was distilled from sodium under a nitrogen atmosphere; dichloromethane, acetonitrile and triethylamine were distilled from calcium hydride under a nitrogen atmosphere; butanol and pentanol were heated under reflux with magnesium, activated by iodine, distilled and stored under argon over molecular sieves (4 Å). Lithium bromide was dried at 160 °C at 0.1 mm Hg for 2 h. Analytical thin-layer chromatography was carried out using precoated, aluminium-backed, silica gel 60 F_{254} plates (E. Merck) and the spots visualised by UV light. Flash column chromatography was performed under positive pressure from a compressed air line using silica gel 60, supplied by BDH (230–400 mesh). Gel permeation chromatography was performed using a polystyrene resin cross-linked with divinylbenzene (Biobeads 1-SX, Bio-Rad, Munich), preswollen in THF. Melting points were determined on a Reichert hotstage and are un$_c$orrected. ^{1}H NMR spectra were recorded on a Bruker AMX400 instrument in $CDCl_3$, [D_6]-acetone or THF/$CDCl_3$ and are reported as follows: chemical shift δ (ppm), [multiplicity, number of protons, coupling constant J [Hz] and assignment]. Residual protic solvent $CHCl_3$ ($\delta_H = 7.24$) and $CD_3C(O)CD_2H$ ($\delta_H = 2.04$) was used as internal reference. ^{13}C NMR spectra were recorded on the same instrument operating at a frequency of 100.5 MHz using the central signals of $CDCl_3$ ($\delta_c = 77.0$) or [D_6]-acetone ($\delta_c = 29.8$) as reference signal. IR spectra were taken on a Perkin–Elmer 1600 FT-IR or a Shimadzu FTIR-8700 spectrometer either as KBr-discs or as film. UV/Vis/NIR-spectra were taken on a Perkin–Elmer Lambda 40 instrument; absorption

maxima (λ_{max}) in nm; extinction coefficients ε in $M^{-1}cm^{-1}$. Mass spectra were recorded on a VG ZAB SE instrument (EI and FAB ionisation) or a Micromass Quattro LC instrument (ES). MALDI-TOF mass spectrometry was carried out on a Fisons VG TOF Spec or a Bruker Biflex III Reflectron MALDI-TOF mass spectrometer using *trans*-3-indoleacrylic acid as a matrix. Microanalyses were carried out on a Perkin–Elmer 2400 CHN machine.

Fluorescence spectra were recorded using a Jobin–Yvon Fluorolog FL3-22 spectrofluorimeter. Fluorescence quantum yields were determined from the integrated emission spectra relative to cresyl violet in methanol ($\Phi_f = 0.54$)[53] and disulfonated aluminium phthalocyanine in water ($\Phi_f = 0.40$).[54] Fluorescence lifetimes were recorded by time-correlated single photon counting using a pulsed 635 nm laser as the excitation source. The equipment used for this measurement has been fully described elsewhere.[55] Singlet oxygen quantum yields were recorded by time-resolved phosphorescence measurements using the method described by Nonell and Braslavsky[56] using 355 nm excitation and perinapthenone as a standard ($\Phi_\Delta = 0.97$).[57]

[2,3,11,12,20,21,29,30-Octakis(triisopropylsilylethynyl)tetra-[6,7]-quinoxalinopor-phyrazinato]-magnesium(II) (5a): A mixture of Mg turnings (39 mg, 1.6 mmol), one small crystal of iodine and butanol (5 mL) was heated under reflux for 4 h. The mixture was then cooled to room temperature and dicyanoquinoxaline **8a** (216 mg, 0.4 mmol) was added in one portion. The reaction was quickly re-heated to reflux for 1 h. The mixture was cooled to room temperature, the solvent removed in vacuo (Kugelrohr), yielding the crude product as a dark blue solid. This was purified by flash chromatography (5% EtOAc/hexane → 40% EtOAc/hexane) followed by gel permeation chromatography using THF as eluent, giving the title compound as a dark blue solid (95 mg, 43 μmol, 43%). ^{1}H NMR (THF/$CDCl_3$, 400 MHz): $\delta = 10.03$ (s, 8H, aryl CH), 1.29 (s, 168H, $Si(CH(CH_3)_2)_3$); ^{13}C NMR (THF/$CDCl_3$, 100.5 MHz): $\delta = 152.3$, 139.6, 138.8, 138.6, 121.5, 103.3, 97.4, 17.3, 10.2; IR (KBr): $\tilde{\nu} = 2943$ cm^{-1} (CH), 2866 (CH), C≡C absorption not visible; UV (THF): λ_{max} (ε) = 244 (175000), 249 (210000), 255 (226000), 389 (288000), 553 (18000), 703 (58000), 731 (54000), 771 nm (510700); MALDI-TOF-MS: *m*/*z*: isotopic cluster peaking at 2187 [M^+]; elemental analysis calcd (%) for $C_{128}H_{176}N_{16}Si_8Mg$ (2187.90): C 70.27, H 8.11, N 10.24; found: C 70.25, H 8.43, N 10.00.

2,3,11,12,20,21,29,30-Octakis(triisopropylsilylethynyl)tetra-[6,7]-quinoxalinoporphyrazinato]-zinc(II) (5b): A suspension of Li metal (1.2 mg, 1.7 mmol) in pentanol (1 mL) was heated to 100 °C until all the lithium had dissolved. The solution was cooled to room temperature, dicyanoquinoxaline **8a** (100 mg, 0.19 mmol) was added, the reaction reheated to 130 °C and held at that temperature for 1 h. To the reaction mixture was then added $Zn(OAc)_2$ (60 mg, 0.33 mmol) and heating was continued for another 3 h. After cooling to room temperature, the solvent was distilled in vacuo (Kugelrohr) and the residue purified by flash chromatography (5% EtOAc/hexane → 40% EtOAc/hexane) followed by gel-permeation chromatography, giving the pure title compound as a dark blue solid (41 mg, 18 μmol, 39%). ^{1}H NMR (THF/$CDCl_3$, 400 MHz): $\delta = 10.03$ (s, 8H, aryl CH), 1.31 (s, 168H, $Si(CH(CH_3)_2)_3$); ^{13}C NMR (THF/$CDCl_3$, 100.5 MHz): $\delta = 152.4$, 139.6, 138.7, 138.0, 121.6, 103.4, 97.5, 17.2, 10.2; IR (KBr): $\tilde{\nu} = 2943$ (CH), 2866 cm^{-1} (CH), C≡C absorption not visible; UV (THF): λ_{max} (ε) = 380 (249000), 547 (27000), 702 (58000), 731 (56000), 770 nm (507000); MALDI-TOF-MS: *m*/*z*: isotopic cluster peaking at 2228 [M^+]; elemental analysis calcd (%) for for $C_{128}H_{176}N_{16}Si_8Zn$ (2228.97): C 68.98, H 7.96, N 10.05; found: C 68.62, H 8.22, N 9.87.

[2,3,11,12,20,21,29,30-Octakis(3,5-di(*tert*-butyl)phenylethynyl)tetra-[6,7]-quinoxalinoporphyrazinato]magnesium(II) (5c): Tetraquinoxalinoporphyrazine **5c** was prepared from dicyanoquinoxaline **8c** (242 mg, 0.4 mmol) analogous to **5a**. To enhance solubility of the starting material, toluene (2 mL) was added to the reaction mixture. The crude product was purified by flash chromatography (eluting first with CH_2Cl_2, then with 20% Et_2O in CH_2Cl_2) followed by gel permeation chromatography (THF), yielding the pure product as a dark green solid (70 mg, 29 μmol, 29%). IR (KBr): $\tilde{\nu}$ = 2960 (CH), 2204 cm^{-1} (C≡C); UV (THF): λ_{max} (ε) = 244 (196000), 249 (232000), 255 (244000), 261 (200000), 286 (139000), 394 (305500), 571 (26100), 704 (59400), 730 (59400), 770 nm (516800); MALDI-TOF-MS: *m*/*z*: isotopic cluster peaking at 2442 [M^+]; elemental analysis calcd (%) for $C_{168}H_{176}N_{16}Mg \cdot 2H_2O$ (2479.69): C 81.38, H 7.32, N 9.04; found: C 81.65, H 7.20, N 8.59.

[2,3,11,12,20,21,29,30-Octakis(4-(triisopropylsilyloxy)phenylethynyl)tetra-[6,7]-quinoxalinoporphyrazinato]-magnesium(II) (5d): Tetraquinoxalinoporphyrazine **5d** was prepared from dicyanoquinoxaline **8d** (160 mg, 0.22 mmol) analogous to **5a**. To enhance solubility of the starting material, toluene (1 mL) was added to the reaction mixture. The crude product was purified by flash chromatography (eluting first with CH_2Cl_2, then with THF) followed by gel-permeation chromatography (THF), giving the pure product as a dark green solid (56 mg, 19 μmol, 35%). IR (KBr): $\tilde{\nu} = 2943$ (CH), 2866 (CH), 2202 cm^{-1} (C≡C); UV (THF): λ_{max} (ε) = 397 (264000), 548 (22000), 693 (43000), 705 (45000), 732 (46000), 772 nm (411000); MALDI-TOF-MS: *m*/*z*: isotopic cluster peaking at 2924 [M^+]; elemental analysis calcd (%) for $C_{176}H_{208}N_{16}O_8Si_8Mg \times 2H_2O$ (2960.71): C 71.39, H 7.22, N 7.57; found: C 71.55, H 7.14, N 7.44.

[2,3,11,12,20,21,29,30-Octakis[4-(((methoxyethoxy)ethoxy)ethoxy)-2,6-dimethyl-phenylethynyl]tetra-[6,7]-quinoxalinoporphyrazinato]magnesium-(II) (5e): Tetraquinoxalinoporphyrazine **5e** was prepared from dicyanoquinoxaline **8e** (55 mg, 73 μmol) analogous to **5a**. The crude product was purified by flash chromatography (impurities were eluted first with Et_2O/CH_2Cl_2, the product was then eluted with THF/MeOH 4:1), followed by gel-permeation chromatography, yielding the title compound as a dark green waxy solid (10 mg, 3.3 μmol, 18%). IR (KBr): $\tilde{\nu} = 2922$ (CH), 2191 (C≡C), 1134 cm^{-1} (C-O); UV (DMSO): λ_{max} (ε) = 266 (159000), 273 (159000), 287 (157000), 584 (13000), 788 nm (38000); MALDI-TOF-MS: *m*/*z*: isotopic cluster peaking at 3066 [M^+]; elemental analysis calcd (%) for $C_{176}H_{192}N_{16}O_{32}Mg \times 2H_2O$ (3103.87): C 68.11, H 6.36, N 7.22; found: C 65.78, H 6.09, N 6.85.

1,6-Bis[4-(triisopropylsilyloxy)phenyl]hexa-1,5-diyne-3,4-dione (6d): BuLi (2.25 mL of a 1.6 M solution in hexane, 3.6 mmol) was added to a cooled (0 °C) solution of the phenylacetylene **11** (1.0 g, 3.6 mmol) in THF (10 mL). The reaction mixture was stirred for 10 min and then transferred through a cannula to a to a cooled (0 °C) solution of LiBr (625 mg, 7.2 mmol) and CuBr (517 mg, 3.6 mmol) in THF (20 mL). The reaction mixture was stirred for 15 min at that temperature after which time a cooled (0 °C) solution of oxalyl chloride (208 mg, 1.64 mmol) in THF (10 mL) was added dropwise. Stirring was continued for an additional 15 min and the reaction mixture was quenched by the addition of saturated aqueous ammonium chloride solution (20 mL) and 1 M hydrochloric acid (4 mL). The organic layer was separated and the aqueous layer extracted with Et_2O (30 mL). The combined organic layers were dried (Na_2SO_4), filtered and the solvents evaporated in vacuo leaving a brownish oil. This was subjected to flash chromatography (5% EtOAc in hexane) giving the title compound as a yellow solid (456 mg, 0.75 mmol, 46%). An analytically pure sample was obtained by recrystallisation from hexane at −20 °C. M.p. 83–85 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 7.57$ (d, 4H, $J = 8.6$ Hz, aryl CH), 6.86 (d, 4H, $J = 8.6$ Hz, aryl CH), 1.23 (m, 6H, C*H*$(CH_3)_2$), 1.07 (d, 36H, $J = 7.4$ Hz, $CH(CH_3)_2$); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta = 172.6$, 159.7, 136.1, 120.5, 111.2, 101.5, 86.8, 17.8, 12.6; IR (KBr): $\tilde{\nu} = 2945$ (s, CH), 2866 (s, CH), 2187 (s, C≡C), 1657 cm^{-1} (s, C=O); UV (CH_2Cl_2): λ_{max} (ε) = 266 (27700), 366 nm (26700); EI-MS (70 eV): *m*/*z* (%): 602 (2.5) [M^+], 546 (48.0) [$M^+ - 2CO$], 301 (100) [½M^+]; elemental analysis calcd (%) for $C_{36}H_{50}O_4$ (602.96): C 71.71, H 8.36; found: C 71.99, H 8.43.

1,6-Bis[4-[(methoxyethoxy)ethoxy]ethoxy]-2,6-dimethylphenyl]hexa-1,5-diyne-3,4-dione (6e): Dione **6e** was prepared analogous to dione **6d** starting from acetylene **15** (2.17 g, 7.43 mmol). After hydrolysis, the layers were separated and the aqueous layer was extracted with CH_2Cl_2 (100 mL). The combined organic layers were dried ($MgSO_4$), the solution then filtered through a pad of silica gel, followed by the removal of the solvent in vacuo which left a brown oil. This was subjected to flash chromatography (EtOAc/CH_2Cl_2 1:1), yielding the product as a yellow solid (870 mg, 1.36 mmol, 40%). An analytically pure sample was obtained by recrystallisation from hexane. M.p. 79–80 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 6.62$ (s, 4H, CH), 4.12 (t, 4H, $J = 4.8$ Hz, OCH_2), 3.82 (t, 4H, $J = 4.8$ Hz, OCH_2), 3.70 (m, 4H, OCH_2), 3.63 (m, 8H, OCH_2), 3.52 (m, 4H, OCH_2), 3.35 (s, 6H, OCH_3), 2.49 (s, 12H, CH_3); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta = 173.3$, 161.3, 146.5, 113.6, 111.6, 100.0, 94.3, 71.9, 70.8, 70.6, 70.5, 69.5, 67.4, 59.0, 21.2; IR (KBr): $\tilde{\nu} = 2895$ (CH), 2180 (C≡C), 1656 (C=O), 1140 (C-O); UV (CH_2Cl_2): λ_{max} (ε) = 273 (25400), 383 nm (31000); EI-MS (70 eV): *m*/*z* (%): 610 (0.6) [$M^+ - CO$], 582 (18.1) [$M^+ - 2CO$], 319 (59.3) [½M^+], 59 (100) [$(CH_3OCH_2CH_2)^+$]; elemental analysis calcd (%) for $C_{36}H_{46}O_{10}$ (638.75): C 67.69, H 7.26; found: C 67.49, H 7.15.

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1,2-Diamino-4,5-dicyanobenzene (7):[36] A mixture of 1,2-diamino-4,5-dibromobenzene[37, 38] (2.0 g, 7.5 mmol) and CuCN (2.7g, 30.0 mmol) in DMF (15 mL) was heated to 140 °C for 15 h. After this time, the reaction was cooled to room temperature and poured into an aqueous ammonia solution (conc. NH_3 (60 mL), water (140 mL)). The resulting suspension was filtered, the collected solid was washed with the same ammonia solution until the filtrate was colourless and the crude product was then washed out with acetone. Removal of the solvent yielded a brownish solid which was recrystallised from H_2O/EtOH (3:1), to give the title compound as off-white needles (300 mg, 1.90 mmol, 25 %). M.p. 272–275 °C (decomp.; lit.:[36] 193–195 °C). Due to this discrepancy, the product was further characterised: ^{1}H NMR ([D$_6$]-acetone, 400 MHz): $\delta = 7.03$ (s, 2H, CH), 5.38 (broad s, 4H, NH_2); ^{13}C NMR ([D$_6$]-acetone, 100.5 MHz): $\delta = 140.0$, 118.0, 117.7, 104.4; IR (KBr): $\tilde{\nu} = 3444$ (NH_2), 3334 (NH_2), 2218 cm^{-1} (C≡N); EI-MS (70 eV): *m*/*z* (%): 158 (100) [M^+]; elemental analysis calcd (%) for $C_8H_6N_4$ (158.63): C 60.75, H 3.82, N 35.42; found: C 61.02, H 3.60, N 35.42.

6,7-Dicyano-2,3-bis(triisopropylsilylethynyl)quinoxaline (8a): 1,2-Diamino-4,5-dicyanobenzene (**7**; 153 mg, 0.85 mmol) was added in one portion at room temperature to a solution of 1,6-bis(triisopropylsilyl)hexa-1,5-diyne-3,4-dione (**6a**)[35] (355 mg, 0.85 mmol) in AcOH (20 mL). The resulting solution was stirred for 20 min at this temperature, before the solvent was removed in vacuo, to yield a brown oil. This was subjected to flash chromatography (10 % EtOAc in hexane) giving the product as a colourless solid (304 mg, 0.56 mmol, 66 %). An analytically pure sample was obtained by recrystallisation from pentane. M.p. 91–93 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 8.46$ (s, 2H, aryl CH), 1.24–1.13 (m, 42H, Si(CH(CH$_3$)$_2$)$_3$); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta = 143.4$, 140.7, 136.1, 114.62, 114.58, 105.0, 102.4, 18.6, 11.2; IR (KBr): $\tilde{\nu} = 2943$ (CH), 2866 (CH), 2237 (C≡N), 2151 cm^{-1} (C≡C); UV (CH_2Cl_2): λ_{max} (ε) = 250 (28100), 288 (48800), 370 (16000), 390 nm (20000); EI-MS (70 eV): *m*/*z* (%): 540 (1.2) [M^+], 498 (21.3) [$M^+ - C(CH_3)_2$], 456 (100) [$M^+ - 2C(CH_3)_2$]; elemental analysis calcd (%) for $C_{32}H_{44}N_4Si_2$ (540.90): C 71.06, H 8.20, N 10.36; found: C 71.14, H 8.39, N 10.41.

6,7-Dicyano-2,3-bis[3,5-di(*tert*-butyl)phenylethynyl]quinoxaline (8c): A suspension of 1,6-bis[3,5-di(*tert*-butyl)phenyl]hexa-1,5-diyne-3,4-dione (**6c**)[29] (412 mg, 0.85 mmol) in AcOH (20 mL) and THF (10 mL) was heated until all the material had dissolved. To this solution was added 1,2-diamino-4,5-dicyanobenzene (**7**; 153 mg, 0.85 mmol) in one portion and the resulting solution was stirred for 20 min at room temperature during which time a yellow precipitate formed. The solvents were evaporated in vacuo and the resulting yellow solid was recrystallised from hexane/toluene (2:1), giving the title compound as a fluffy yellow solid (350 mg). The mother liquor was evaporated in vacuo and the obtained solid recrystallised, giving a second crop (35 mg) of the product (overall 385 mg, 75 %). M.p. 275–279 °C (decomp.); ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 8.47$ (s, 2H, quinoxaline CH), 7.50 (t, 2H, $J = 1.7$ Hz, phenyl CH), 7.47 (d, 4H, $J = 1.7$ Hz, phenyl CH), 1.24 (s, 36H, CH_3; ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta = 151.4$, 145.1, 140.8, 136.1, 126.7, 125.4, 119.6, 114.8, 114.6, 102.3, 85.1, 34.8, 31.2; IR (KBr): $\tilde{\nu} = 2963$ (CH), 2208 cm^{-1} (C≡N); UV (CH_2Cl_2): λ_{max} (ε) = 249 (30700), 280 (35600), 296 (31800), 409 nm (21000); EI-MS (70 eV): *m*/*z* (%): 604 (19.0) [M^+], 548 (65.1) [$M^+ - C(CH_3)_3$+H], 533 (45.0) [$M^+ - C(CH_3)_3 - CH_3$+H], 287 (31.8), 57 (100) [$C(CH_3)_3^+$]; elemental analysis calcd (%) for $C_{42}H_{44}N_4$ (604.84): C 83.40, H 7.33, N 9.26; found: C 83.34, H 7.54, N 9.21.

6,7-Dicyano-2,3-bis[4-(triisopropylsilyloxy)phenylethynyl]quinoxaline (8d): A suspension of dione **6d** (200 mg, 0.33 mmol) in AcOH (6 mL) was heated until all the material had dissolved. To this solution was added 1,2-diamino-4,5-dicyanobenzene (**7**; 53 mg, 0.33 mmol) in one portion and the reaction mixture was stirred for 20 min at room temperature. Removal of the solvent in vacuo yielded a brownish solid which was recrystallised from *i*PrOH/MeOH/EtOAc, giving the title compound as yellow needles (191 mg, 0.26 mmol, 80 %). M.p. 232–234 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 8.42$ (s, 2H, quinoxaline-CH), 7.58 (d, 4H, $J = 8.6$ Hz, phenyl-CH), 6.89 (d, 4H, $J = 8.6$ Hz, phenyl-CH), 1.27 (m, 6H, C*H*(CH$_3$)$_2$), 1.10 (d, 36H, $J = 7.3$ Hz, CH(C*H*$_3$)$_2$); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta =$ 158.8, 144.9, 140.7, 136.0, 134.6, 120.5, 114.9, 114.4, 112.8, 101.6, 86.2, 17.8, 12.7; IR (KBr): $\tilde{\nu} = 2945$ (CH), 2866 (CH), 2203 cm^{-1} (C≡N); UV (CH_2Cl_2): λ_{max} (ε) = 254 (36600), 279 (38300), 302 (34000), 339 (38400), 421 nm (30600); EI-MS (70 eV): *m*/*z* (%): 724 (100) [M^+], 681 (54.0) [$M^+ - CH(CH_3)_2$], 639 (23.1) [$M^+ - CH(CH_3)_2 - C(CH_3)_2$]; elemental analysis calcd (%) for $C_{44}H_{52}N_4O_2Si_2$ (725.09): C 72.89, H 7.23, N 7.73; found: C 73.08, H 7.08, N 7.65.

6,7-Dicyano-2,3-bis[4-[(methoxyethoxy)ethoxy]ethoxy]-2,6-dimethylphenylethynyl]-quinoxaline (8e): Dione **6e** (59.4 mg, 0.093 mmol) was added to a suspension of 1,2-diamino-4,5-dicyanobenzene **7** (14.7 mg, 0.093 mmol) in AcOH (2 mL). The reaction mixture was warmed until all compounds had dissolved and further stirred at room temperature for 20 min. Subsequently the solvent was removed in vacuo. The residual brown oil was purified by flash chromatography (CH_2Cl_2/EtOAc 2:1 → 1:2) to yield the title compound as an orange solid (60.0 mg, 0.079 mmol, 85 %). An analytically pure sample was obtained by recrystallisation from EtOH. M.p. 97–99 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 8.37$ (s, 2H, quinoxaline CH), 6.56 (s, 4H, phenyl CH), 4.07 (t, 4H, $J = 4.8$ Hz, OCH_2), 3.80 (t, 4H, $J =$ 4.8 Hz, OCH_2), 3.67 (m, 4H, OCH_2), 3.61 (m, 8H, OCH_2), 3.49 (m, 4H, OCH_2), 3.31 (s, 6H, OCH_3), 2.36 (s, 12H, CH_3); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta = 160.0$, 144.9, 143.9, 140.8, 135.9, 114.9, 114.1, 113.4, 112.9, 98.9, 93.4, 71.9, 70.8, 70.6, 70.5, 69.5, 67.3, 59.0, 21.2; IR (KBr): $\tilde{\nu} = 2872$ (CH), 2193 (C≡N), 1136 cm^{-1} (C-O); UV (CH_2Cl_2): λ_{max} (ε) = 228 (22700), 275 (42200), 351 (19200), 432 nm (23800); ES-MS: *m*/*z* (%): 761 (100) [MH^+]; elemental analysis calcd (%) for $C_{44}H_{48}N_4O_8$ (760.88): C 69.46, H 6.36, N 7.36; found: C 69.06, H 6.29, N 7.37.

1-Iodo-4-(triisopropylsilyloxy)benzene (10): Chlorotriisopropylsilane (4.84 mL, 4.38 g, 22.7 mmol) was added at room temperature to a solution of 4-iodophenol (**9**; 5.0 g, 22.7 mmol) and imidazole (3.87 g, 56.8 mmol) in CH_2Cl_2 (40 mL). The reaction mixture was then stirred for 24 h at the same temperature. Subsequently the solvent was evaporated in vacuo and the residue was filtered through a pad of silica gel (hexane) to yield the product as a colourless oil (7.99 g, 21.2 mmol, 93 %). ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 7.47$ (d, 2H, $J = 8.7$ Hz, aryl CH), 6.63 (d, 2H, $J = 8.7$ Hz, aryl CH), 1.21 (m, 3H, C*H*(CH$_3$)$_2$), 1.07 (d, 18H, $J = 7.2$ Hz, CH(C*H*$_3$)$_2$); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta = 156.0$, 138.2, 122.3, 83.2, 17.8, 12.6; IR (film): $\tilde{\nu} =$ 2943 (CH), 2866 cm^{-1} (CH); EI-MS (70 eV): *m*/*z* (%): 376 (54.6) [M^+]; 333 (100) [$M^+ - CH(CH_3)_2$], 305 (33.4), 277 (51.2), 263 (26.9); HR-MS (FAB): calcd for $C_{15}H_{25}IOSi$: 376.0719; found: 376.0732.

1-Ethynyl-4-(triisopropylsilyloxy)benzene (11): A solution of 1-iodo-4-(triisopropylsilyloxy)benzene (**10**; 2.83 g, 7.5 mmol) in toluene (20 mL) was purged with Ar for 5 min. To this solution was added Et_3N (3.5 mL), 2-methyl-but-3-yn-2-ol (0.89 mL, 0.76 g, 9.0 mmol), [$PdCl_2(PPh_3)_2$] (100 mg, 0.14 mmol) and CuI (30 mg, 0.16 mmol) at room temperature. The reaction mixture was stirred for 30 min at the same temperature, after which time a black suspension was obtained. The volatile components were removed in vacuo. The residue was filtered through a pad of silica gel (30 % EtOAc in hexane) to give a brown oil, which was dissolved in PhH (30 mL). Subsequently crushed pellets of KOH (0.9 g, 16.1 mmol) were added. The reaction mixture was heated to reflux for 3 h, cooled to room temperature and the solvent was removed in vacuo. The residue was filtered through a pad of silica gel (hexane), yielding the title compound as a colourless oil (1.42 g, 5.1 mmol, 68 %). ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 7.34$ (d, 2H, $J =$ 8.6 Hz, aryl CH), 6.79 (d, 2H, $J = 8.6$ Hz, aryl CH), 2.97 (s, 1H, C≡CH), 1.24 (m, 3H, C*H*(CH$_3$)$_2$), 1.07 (d, 18H, $J = 7.3$ Hz, CH(C*H*$_3$)$_2$); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta = 156.7$, 133.6, 119.9, 114.4, 83.8, 75.8, 17.8, 12.6; IR (film): $\tilde{\nu} = 3317$ (acetylenic CH), 2945 (CH), 2866 (CH), 2108 cm^{-1} (C≡C); EI-MS (70 eV): *m*/*z* (%): 274 (34.9) [M^+], 231 (100) [$M^+ - CH(CH_3)_2$], 203 (39.4), 175 (89.8), 161 (63.0); HR-MS (FAB): calcd for $C_{17}H_{26}OSi$+H: 275.1831; found: 275.1834.

1-Iodo-4-[[(methoxyethoxy)ethoxy]ethoxy]-2,6-dimethylbenzene (13): Anhydrous potassium carbonate (6.26 g, 45.4 mmol) was added at room temperature to a solution of 2-[(methoxyethoxy)ethoxy]ethyl bromide[45] (5.15 g, 22.7 mmol) and 4-iodo-3,5-dimethylphenol (**12**)[44] (9.03 g, 27.2 mmol) in CH_3CN (30 mL). The reaction mixture was heated to reflux for 15 h. After this time, the mixture was cooled to room temperature, poured into water (150 mL), neutralised with 1 M HCl and extracted with EtOAc (2 × 100 mL). The combined organic extracts were dried ($MgSO_4$) and filtered. The solvents were removed in vacuo to leave a brown oil, which was subjected to flash chromatography (EtOAc/hexane 1:1) to yield the product as a pale yellow oil (6.73 g, 17.1 mmol, 75 %). ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 6.65$ (s, 2H, CH), 4.06 (t, 2H, $J = 4.9$ Hz, OCH_2), 3.80 (t, 2H, $J = 4.9$ Hz, OCH_2), 3.70 (m, 2H, OCH_2), 3.64 (m, 4H, OCH_2), 3.52 (m, 2H, OCH_2), 3.35 (s, 3H, OCH_3), 2.40 (s, 6H, CH_3); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta = 158.3$, 142.7, 113.5, 97.2, 71.9, 70.8, 70.6, 70.5, 69.6, 67.3, 59.0, 29.7; IR (film): $\tilde{\nu} = 2876$ (CH), 1111 cm^{-1} (C-O); EI-MS (70 eV): *m*/*z*

(%): 394 (41.9) [M^+], 248 (32.2), 103 (27.7), 59 (100) [$(CH_3OCH_2CH_2)^+$]; HR-MS (FAB): calcd for $C_{15}H_{23}O_4I$+H: 395.0719; found: 395.0735.

1-[[(Methoxyethoxy)ethoxy]ethoxy]-3,5-dimethyl-4-(triethylsilylethynyl)-benzene (14): A solution of compound **13** (6.22 g, 15.8 mmol) and triethylsilylacetylene (2.21 g, 2.82 mL, 15.8 mmol) in Et_3N (40 mL) was purged with Ar for 5 min. To this solution was added $(PPh_3)_2PdCl_2$ (240 mg, 0.34 mmol) and the reaction mixture was heated to reflux. To the refluxing reaction mixture was added CuI (130 mg, 0.68 mmol) and reflux was continued for 2 h. After this time, the reaction mixture had turned black. It was cooled to room temperature, the solvent was removed in vacuo and the residue was filtered through a pad of silica gel (Et_2O) yielding the product as a pale yellow oil (5.29 g, 13.0 mmol, 83 %). ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 6.57$ (s, 2H, CH), 4.07 (t, 2H, $J = 4.9$ Hz, OCH_2), 3.81 (t, 2H, $J = 4.9$ Hz, OCH_2), 3.70 (m, 2H, OCH_2), 3.65 (m, 4H, OCH_2), 3.53 (m, 2H, OCH_2), 3.35 (s, 3H, OCH_3), 2.38 (s, 6H, CH_3), 1.03 (t, 9H, $J = 7.9$ Hz, $Si(CH_2CH_3)_3$), 0.65 (q, 6H, $J = 7.9$ Hz, $Si(CH_2CH_3)_3$); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta =$ 158.1, 142.3, 115.8, 112.9, 103.9, 98.2, 71.9, 70.8, 70.6, 70.5, 69.6, 67.2, 59.0, 21.3, 7.6, 4.6; IR (film): $\tilde{\nu} = 2954$ (CH), 2876 (CH), 2145 (C≡C), 1126 cm^{-1} (C-O); EI-MS (70 eV): m/z (%): 406 (52.3) [M^+], 59 (100) [$(CH_3OCH_2CH_2)^+$]; HR-MS (FAB): calcd for $C_{23}H_{38}O_4Si$+H: 407.2618; found: 407.2634.

1-Ethynyl-4-[[(methoxyethoxy)ethoxy]ethoxy]-2,6-dimethylbenzene (15): Tetrabutylammonium fluoride (3.50 mL of a 1.0 M solution in THF containing ≈3 % water, 3.50 mmol) was added at room temperature to a solution of compound **14** (1.35 g, 3.33 mmol) in THF (20 mL) and the reaction mixture was stirred for 15 min. After this time, the solvent was evaporated in vacuo and the residue was filtered through a pad of silica gel (EtOAc/hexane 1:1), giving the product as a pale yellow oil (970 mg, 3.33 mmol, 100 %). ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 6.57$ (s, 2H, aryl CH), 4.07 (t, 2H, $J = 4.9$ Hz, OCH_2), 3.81 (t, 2H, $J = 4.9$ Hz, OCH_2), 3.70 (m, 2H, OCH_2), 3.63 (m, 4H, OCH_2), 3.52 (m, 2H, OCH_2), 3.39 (s, 1H, CCH), 3.35 (s, 3H, OCH_3), 2.38 (s, 6H, CH_3); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta = 158.3$, 142.6, 114.4, 113.0, 83.7, 81.2, 71.8, 70.8, 70.6, 70.5, 69.6, 67.2, 59.0, 21.2; IR (film): $\tilde{\nu} = 3255$ (acetylenic CH), 2877 (CH), 2095 (C≡C), 1152 cm^{-1} (C-O); EI-MS (70 eV): m/z (%): 292 (100) [M^+], 146 (57.7), 59 (97.4); HR-MS (FAB): calcd for $C_{17}H_{24}O_4$+Na: 315.1572; found: 315.1560.

[2,3,11,12,20,21,29,30-Octakisdodecyltetra-[6,7]-quinoxalinoporphyrazinato]-magnesium(II) (16): Tetraquinoxalinoporphyrazine **16** was prepared from dicyanoquinoxaline (**17**; 206 mg, 0.4 mmol) analogous to tetraquinoxalinoporphyrazine **5a**. The crude product was purified by flash chromatography (eluting first with CH_2Cl_2, then with 20 % Et_2O in CH_2Cl_2) followed by gel permeation chromatography (THF), yielding the pure product as a dark blue solid (64 mg, 31 μmol, 31 %). IR (KBr): $\tilde{\nu} =$ 2922 (CH), 2852 cm^{-1} (CH); UV (THF): λ_{max} (ε) = 271 (81 500), 310 (79 400), 364 (133 100), 483 (7300), 660 (52 500), 700 (50 400), 735 nm (431 000); MALDI-TOF-MS: m/z: isotopic cluster peaking at 2091 [M^+]; elemental analysis calcd (%) for $C_{136}H_{208}N_{16}Mg$ (2091.56): C 78.10, H 10.02, N 10.72; found: C 77.76, H 10.22, N 10.67.

6,7-Dicyano-2,3-bisdodecylquinoxaline (17): Quinoxaline **17** was prepared analogous to quinoxaline **8a** from 4,5-diaminophthalonitrile (**7**) and hexacosa-13,14-dione.[46] The crude product was recrystallised from EtOH, giving the title compound as a colourless solid (319 mg, 0.62 mmol, 72 %). M.p. 77 – 80 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): $\delta = 8.44$ (s, 2H, aryl CH), 3.02 (t, 4H, $J = 7.7$ Hz, CH_2CH_2C=N), 1.81 (quintet, 4H, $J = 7.6$ Hz, $CH_2CH_2CH_2C$=N), 1.46 – 1.20 (m, 36H, alkyl chain), 0.86 (t, 6H, $J =$ 6.8 Hz, CH_3); ^{13}C NMR ($CDCl_3$, 100.5 MHz): $\delta = 161.8$, 141.6, 136.4, 115.2, 113.1, 35.4, 31.9, 29.65, 29.63, 29.61, 29.52, 29.50, 29.42, 29.34, 27.7, 22.7, 14.1; IR (KBr): $\tilde{\nu} = 2916$ (CH), 2848 (CH), 2235 cm^{-1} (C≡N); UV (CH_2Cl_2): λ_{max} (ε) = 225 (26 800), 250 (60 100), 321 (5200), 335 nm (5700); EI-MS (70 eV): m/z (%): 516 (13.8) [M^+], 362 (100) [$M^+ - 11\,CH_2$]; elemental analysis calcd (%) for $C_{34}H_{52}N_4$ (516.81): C 79.02, H 10.14, N 10.84; found: C 78.71, H 10.33, N 10.71.

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