Homolytic Alkylation of Some 3,4-Quinolinediyl Bis-sulfides under Minisci Reaction Conditions[#]

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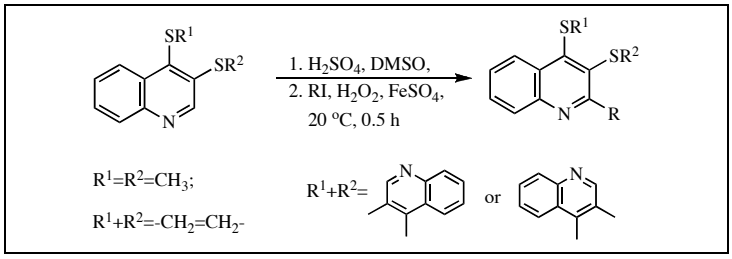

Reaction of hydrogen sulfate of 3,4-quinolinediyl bis-sulfides **1a**, **2a**, **3a**, and **4a** with isopropyl and cyclohexyl radicals formed from alkyl iodide/hydrogen peroxide/DMSO/Fe^{++} salt system took place at α-quinolinyl position and led to the respective mono- and dialkyl derivatives **1b-e**, **2b-e**, **3b,c**, and **4b,c**. Action of sodium methoxide towards isopropyl derivatives **1b,c** and **2b,c** caused the 1,4-dithiin ring opening to form (after *S*-methylation) derivatives of 3,4'- and 3,3'-diquinolinyl sulfides **6a,b** and **7a,b**.

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INTRODUCTION

Reactions of bis-hydrogensulfate of thioquinanthrene **1a** performed under Minisci reaction conditions with radicals formed from DMF took place at α-quinolinyl positions and led to the respective *N*,*N*-dimethyl-carbamoyl- and *N*-methyl-*N*-formylaminomethyl derivatives. [1] The same reaction course was observed for salts of bis-sulfides **2a** and **3a**. [2,3]

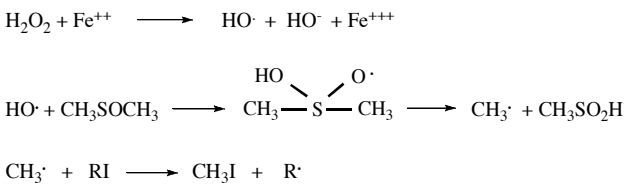
In order to extend this study we turned now our attention to the homolytic alkylation of thioquinanthrene (**1a**) and related quinolinediyl bis-sulfides **2a**, **3a**, **4a** as a source of 2,3,4-trisubstituted quinolines.

RESULTS AND DISCUSSION

Protonated azines undergo homolytic substitution with alkyl radicals at α- and (or) γ- positions under Minisci reaction conditions [4]. For this purpose alkyl radicals could be usually prepared from carboxylic acids, alkyl iodides, alkenes or *N*-alkylamides [4]. Several reagent systems were usually applied to generate *in situ* alkyl radicals from alkyl iodides: i) *tert*-butyl peroxide/ hydrogen peroxide/ Fe^{++} ions, [4] ii) acetone/ hydrogen peroxide/ Fe^{++} ions, [5,6] iii) benzoyl peroxide / Fe^{++} or Cu^{+} ions, [4] iv) hydrogen peroxide/ DMSO/Fe^{++} salt [4,5,6] and v) arenediazonium salt/ Fe^{++} or Cu^{+} ions. [4]

Taking into account the very poor solubility of thioquinanthrene **1a** in aqueous or even aqueous -DMSO solutions typically applied for the Minisci alkylation reaction, we chose DMSO both as a solvent and as a substrate for the formation of radicals and, therefore, we decided to use for this study the alkyl iodide/hydrogen peroxide/ DMSO/Fe^{++} salt system. This acts as presented on Scheme 1 to generate simultaneously, methyl and alkyl radicals. [5,6]

Scheme 1



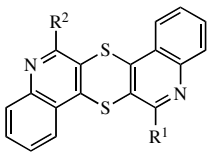
Considering thioquinanthrene **1a** as reference compound, the reactivity of **1a** towards alkylating species formed from methyl, isopropyl, *tert*-butyl and cyclohexyl iodides was evaluated. The reaction was performed by dropping hydrogen peroxide to a solution of bis(hydrogen sulfate) of bis-sulfide **1a**, alkyl iodide and ferrous sulfate in DMSO at rt for 0.5 h. After dilution with water, the reaction mixture was neutralized with conc. aqueous ammonia, and the solid composed of products and non-consumed substrate was isolated by filtration. After typical work-up, the mixture was analyzed both by tlc and by ^{1}H NMR spectra. Alkylation of thioquinanthrene **1a** was observed only in the case of isopropyl iodide and cyclohexyl iodide. For both iodides mono and dialkylation products at α-quinolinyl positions were formed (see Table). Only at a lower concentration of reaction mixture components (up to 100 mL of DMSO per 1 mol. eqv. of quinoline unit) did the reaction result in dialkylation products **1c** or **1e** with yield up to 90 %.

Mono-isopropylderivative **1b** was converted to isopropyl-cyclohexyl derivative **1f** under this condition.

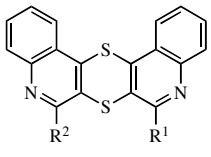
To evaluate the structural requirement for the substitution at α-quinolinyl position, further cyclic **2a** and **4a** and open chain 3,4-quinolinediyl bis-sulfides **3a** and **5** were chosen.

For each molar equivalent of quinoline unit, 5 molar equivalents of alkyl iodide, 5 molar equivalents of H_2O_2 and 0.05 molar equivalent of ferrous sulfate were applied.

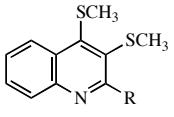
Scheme 2



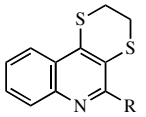
1a, R^1=R^2=H
1b, R^1=isopropyl, R^2=H
1c, R^1=R^2=isopropyl
1d, R^1=cyclohexyl, R^2=H
1e, R^1=R^2=cyclohexyl,
1f, R^1=isopropyl, R^2=cyclohexyl



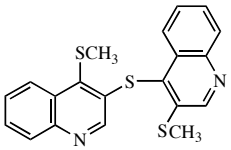
2a, R^1=R^2=H
2b, R^1=isopropyl, R^2=H
2c, R^1=R^2=isopropyl
2d, R^1=cyclohexyl, R^2=H
2e, R^1=R^2=cyclohexyl,



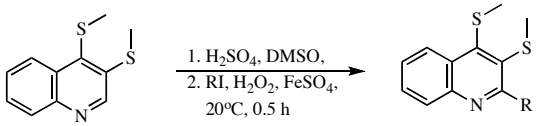
3a, R=H
3b, R=isopropyl
3c, R=cyclohexyl



4a, R=H
4b, R=isopropyl
4c, R=cyclohexyl



5



1a
2a
3a
4a

1b and **1c,** or **1d** and **1e**
2b and **2c,** or **2d** and **2e**
3b or **3c**
4b or **4c**

As in the case of **1a**, only alkylation of **2a**, **3a** and **4a** with isopropyl and cyclohexyl iodides was observed, whereas diquinolinyl sulfide **5** appeared to be unreactive. No reaction with methyl radicals as well as with *t*-butyl iodide was noted for any bis-sulfides studied.

The most diagnostic data in the structure assignment of **1b-e**, **2b-e**, **3b** and **4b** come from ^{1}H NMR spectra. They showed the presence of only one α-quinolinyl proton singlet for monoalkyl derivatives **1b**, **1d**, **2b**, **2d**, but no singlet of α-quinolinyl proton was observed for dialkyl derivatives **1c**, **1e**, **2c**, **2e** and for **3b**, **4b**. This proves that alkyl groups were introduced in α-quinolinyl positions.

Benzene ring proton assignment for mono-isopropyl derivatives **1b** and **2b** was deduced from concerted use of COSY, HSQC and HMBC spectra (see Scheme 4). Downfield shifts of benzene ring protons in all

Table

Entry	Substrate	Alkyl iodide	Composition of products and substrate mixture
1	**1a**	isoPr-I	**1a** (50 %), **1b** (19 %), **1c** (30 %)
2	**1a**	isoPr-I *)	**1a** (2 %), **1b** (6 %), **1c** (90 %)
3	**1a**	cyclohex-I	**1a** (62 %), **1d** (21 %), **1e** (15 %)
4	**1a**	cyclohex-I *)	**1a** (2 %), **1d** (5 %), **1e** (90 %)
5	**2a**	isoPr-I	**2a** (53 %), **2b** (21 %), **2c** (22 %)
6	**2a**	isoPr-I *)	**2a** (1 %), **2b** (7 %), **2c** (90 %)
7	**2a**	cyclohex-I	**2a** (63 %), **2d** (24 %), **2e** (11 %)
8	**3a**	isoPr-I	**3a** (67 %), **3b** (32 %)
9	**3a**	isoPr-I	**3a** (71 %), **3c** (28 %)
10	**4a**	isoPr-I	**4a** (80 %), **4b** (19 %)
11	**4a**	isoPr-I	**4a** (82 %), **4c** (16 %)
12	**1b**	cyclohex-I *)	**1f** (95 %)

*) at 4-times lower concentration of reaction mixture components in DMSO

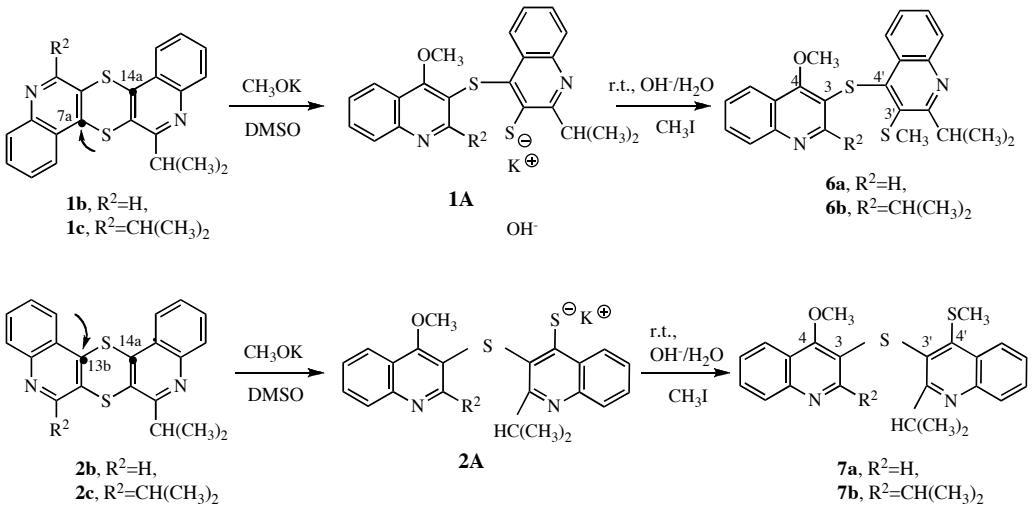
thioquinanthrene derivatives **1a**, **1b** and **1c** decrease in the same order: $H_{6\text{-quinolinyl}}$ (H-2 or H-9) > $H_{7\text{-quinolinyl}}$ (H-3 or H-10) > $H_{8\text{-quinolinyl}}$ (H-4 and H-11) > $H_{5\text{-quinolinyl}}$ (H-1 or H-8). The same shift order could be also deduced from NMR spectra of isothioquinanthrene derivatives **2a**, **2b** and **2c** as well as for sets consisting of **3a**, **3b**, **3c** and **4a**, **4b** and **4c**.

Nucleophilic desulfidation at γ-quinolinyl-sulfur bond in thioquinanthrene **1a** caused the 1,4-dithiin ring opening and led to 3'-quinolinethiolates of type **1A**, which were subsequently trapped by alkylation in the form of 4-nucleophilo-3'-alkylthio-3,4'-diquinolinyl sulfides of type **6**. The same procedure applied for compounds **6** resulted finally in two molecules of 4-nucleophilo-3-quinolinyl sulfides with the same or with non-identical nucleophile moieties. [7] As the entry point in the approach to obtain the 2,3,4-trisubstituted quinoline units from di- and monoisopropyl derivatives **1b**,**c** and **2b**,**c**, they were subjected to reaction with potassium methoxide (3 molar equivalents) followed by methylation. This resulted in the expected 3,4'- and 3,3'-diquinolinyl sulfides **6a** (89 %) and **6b** (85 %) or **7a** (90 %) and **7b** (87 %), respectively.

As mentioned above, the action of nucleophile engaged the γ-quinolinyl positions in 1,4-dithiin ring of **1a** or **1b**.

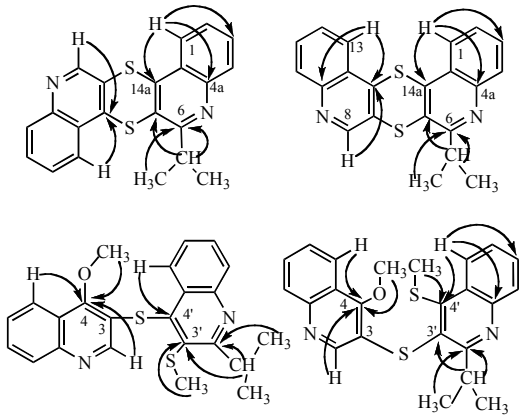
However, the action of methoxide (3 mol. eqv.) affected regioselectively the γ-quinolinyl positions in 3,4-disubstituted quinoline units (*i.e.* C-7a in **1b** and C-13b in **2b**) and led to **6a** or **7a** as final products, whereas the γ-quinolinyl carbons in 2,3,4-trisubstituted quinoline moieties (*i.e.* C-14a in **1b** and C-14a in **2b**) remained

Scheme 3



unaffected. The structure of compounds **6a** or **7a** was deduced from 2D ^{1}H and ^{13}C NMR spectra using HMQC and HSQC techniques (see Scheme 4).

Scheme 4



We were unable to find a satisfactory explanation of regioselectivity of methoxy desulfidation of **1b** and **2b** One would expect that the orientation of this reaction depends on steric factor at γ-quinolinyl carbons (marked with •, Scheme 3), induced by an isopropyl group.

However, calculations of S-C-C-S torsion angle, of distortion of sulfur substituents from the parent pyridine ring plane and of the energy of transition state at γ-quinolinyl carbons (marked with •) with HyperChem program [8] gave very close values for **1a**, **1b** and **1c**. Meanwhile, competitive experiment with a (1:1:1) mixture of thioquinanthrene **1a**, monoisopropylderivative **1b** and diisopropylderivative **1c** treated with 2 molar equivalents of potassium methoxide (DMSO, 70 °C, 1 h) enabled a 68 % conversion of non-substituted substrate **1a**, a 62 % conversion of monoisopropylderivative **1b** and only a 34 % conversion of **1c**.

CONCLUSIONS

3,4-Quinolinediyl bis-sulfides **1a**, **2a**, **3a** and **4a** (in the form of respective quinolinium salts) were alkylated at α-quinolinyl positions with isopropyl and cyclohexyl radicals formed from alkyl iodide/hydrogen peroxide/ DMSO/Fe^{++} salt system to the respective mono- and dialkyl derivatives **1b-e**, **2b-e**, **3b,c** and **4b,c**. X-ray study showed that both α-quinolinyl positions in sulfide **5** were hindered by neighbouring substituents, [9] so probably for steric reasons no α-quinolinyl-alkylation of 3',4-dimethyl-thio-3,4'-diquinolinyl sulfide **5** was observed. Methoxy desulfidation leading to 1,4-dithiin ring opening in 6-mono-isopropyl derivatives **1b** and **2b** occurs at 3,4-disubstituted quinoline units to give the respective 3,4'- or 3,3'-diquinolinyl sulfide derivatives **6a** and **7a**.

EXPERIMENTAL

All melting points are uncorrected. All NMR spectra were recorded on a Bruker AVANS 400 spectrometer operating at 400.22 MHz and 100.64 MHz for ^{1}H and ^{13}C nuclei, respectively, in deuterochloroform solutions with tetramethylsilane (δ 0.0 ppm) as internal standard. Two-dimensional ^{1}H-^{13}C HSQC and HMBC experiments were performed using standard Bruker software HSQCGP and HMBCGP, respectively, and the following parameters: the spectral widths in F_2 and F_1 were *ca* 5 kHz for ^{1}H and 16.7 kHz for ^{13}C, the relaxation delay was 1.5 s, the refocusing in the HSQC experiment was 1.7 ms and the delay for long-range evolutions was 50 ms in $^{1}H/^{13}C$ HMBC. 2D spectra were acquired as 2048 x 1024 hypercomplex files, with 1-4 transients.

TLC analyses were performed employing Merck's aluminium oxide 60 F_{254} neutral (type E) plates using a solution of carbon tetrachloride-dichloromethane (1:1, v/v) as eluent. Thioquinan-

threne, *i.e.* 1,4-dithiino[2,3-*c*:5,6-*c*']diquinoline **1a**, isothioquinanthrene, *i.e* 1,4-dithiino[2,3-*c*:6,5-*c*']diquinoline **2a**, 3',4-dimethylthio-3,4'-diquinolinyl sulfide **5**, 3,4-dimethylthioquinoline **3a** and 2,3-dihydro-1,4-dithiino[5,6-c]quinoline **4a**, were prepared as reported previously. [2,3,9]

Reactions of quinolinediyl bis-sulfides 1a and 2a with radicals formed from isopropyl and cyclohexyl iodides. Bis-sulfide (0.8 mmol) was dissolved in conc. sulfuric acid (3 mL). DMSO (40 mL) was poured on stirring into the solution, which was cooled down to rt. Heptahydrate of ferrous sulfate (0.04 g, 0.16 mmol) and alkyl iodide (8 mmol) were then added. 0.8 mL (8 mmol) of 30 % H_2O_2 was subsequently added drop by drop, where each next drop was added when the solution turned from red to orange. The mixture was poured into 100 ml of cold water and neutralized with conc. aqueous ammonia to pH ~6. The solid was collected by filtration, washed with water and air-dried. This material was boiled with 30 ml of xylene and hot filtered. The filtrate was evaporated to dryness. The residue was separated by column chromatography [aluminium oxide / carbon tetrachloride-methylene chloride (1 : 1, v/v) as eluent] to give **1a** (R_f=0.14), **1b** (R_f=0.38), **1c** (R_f=0.60), **1d** (R_f=0.33), **1e** (R_f=0.51), **1f** (R_f=0.61) or give **2a** (R_f=0.13), **2b** (R_f=0.40), **2c** (R_f=0.58), **2d** (R_f=0.34), **2e** (R_f=0.55).

The same procedure was applied for the reaction with 3,4-dimethylthioquinoline **3a** and 2,3-dihydro-1,4-dithiino-[5,6-c]quinoline **4a**, for each molar equivalent of quinoline unit, 5 mol. eqvs of alkyl iodide, 5 mol. eqvs of H_2O_2 and 0.05 mol. eqvs of ferrous sulfate were used. However, the reaction mixture components were isolated by extraction with dichloromethane, followed by typical work-up and column chromatography separation as described above to give **3a** (R_f=0.15), **3b** (R_f=0.45), **3c** (R_f=0.63) or give **4a** (R_f=0.20), **4b** (R_f=0.45), **4c** (R_f=0.60). In the case of 3',4-dimethylthio-3,4'-diquinolinyl sulfide **5**, non-converted substrate was isolated by filtration.

6-Isopropylthioquinanthrene (**1b**). This compound was obtained as bright yellow plates (xylene), mp 190-191°C; ^{1}H nmr, δ: [δ_C for carbons from single bond and / long-range proton-carbon correlations]: 1.47 [(d, ^3J = 6.8 Hz, 6H, 2 x CH_3); 21.7 (CH_3) / 34.2 (CH), 163.4 (C-6], 3.18 [(septet, ^3J = 6.8 Hz, 1H, CH); 34.2 (CH) / 163.4 (C-6), 126.7 (C-6a)], 7.59 [(ddd, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, ^4J = 1.3 Hz, H-2); 126.9 (C-2) / 129.6 (C-4), 126.1 (C-14b)], 7.68 [(ddd, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, ^4J = 1.3 Hz, H-9); 127.9 (C-9) / 130.0 (C-11), 127.1 (C-7b)], 7.71 [ddd, ^3J = 8.4 Hz, ^3J = 6.9 Hz, ^4J = 1.4 Hz, 1H, H-3); 129.9 (C-3) / 123.7 (C-1), 146.6 (C-4a)], 7.75 [(ddd, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, ^4J = 1.4 Hz, H-10); 130.1 (C-10) / 147.0 (C-11a), 123.7 (C-8)], 8.07 [(dd, 1H, ^3J = 8.4 Hz, ^4J = 1.3 Hz, H-4); 129.6 (C-4) / 126.9 (C-2), 126.1 (C-14b)], 8.13 [(dd, 1H, ^3J = 8.4 Hz, ^4J = 1.3 Hz, H-11); 130.0 (C-11) / 127.1 (C-7b), 127.9 (C-9)], 8.37 [(dd, 1H, ^3J = 8.4 Hz, ^4J = 1.4 Hz, H-1); 123.7 (C-1) / 144.3 (C-14a), 146.6 (C-4a), 129.9 (C-3)], 8.47 [(dd, 1H, ^3J = 8.4 Hz, ^4J = 1.4 Hz, H-8); 123.7 (C8) / 144.5 (C-7a), 147.0 (C-11a), 130.1 (C-10)], 8.92 [(s, 1H, H-13); 148.0 (C-13) / 147.0 (C-11a), 144.5 (C-7a), 127.1 (C-7b), 128.2 (C-13a)]. *Anal.* Calcd for $C_{21}H_{16}N_2S_2$: C 69.97, H 4.44, N 7.77. Found: C 69.90, H 4.34, N 7.67.

6,12-Diisopropylthioquinanthrene (**1c**). This compound was obtained as bright yellow plates (xylene), mp. 151-153°C, ^{1}H nmr, δ(ppm): 1.47-1.49 (d, 12H, ^3J = 6.8 Hz, 4 x CH_3), 4.00 (septet, 2H, ^3J = 6.8 Hz, 2 x CH), 7.59-7.63 (m, 2H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-2 and H-9), 7.69-7.73 (m, 2H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-3 and H-10), 8.06–8.08 (dd, 2H, ^3J = 8.4 Hz, H-4 and H-11), 8.47-8.50 (dd, 2H, ^3J = 8.4 Hz, H-1 and H-8). *Anal.* Calcd for $C_{24}H_{22}N_2S_2$: C 71.61, H 5.51, N 6.96. Found: C 71.68, H 5.55, N 6.80.

6-Cyclohexylthioquinanthrene (**1d**). This compound was obtained as bright yellow plates (xylene), mp. 261-263°C. ^{1}H nmr, δ(ppm): 1.38-2.06 (m, 10H, 5 x CH_2), 3.56-3.63 (m, 1H, CH), 7.57-7.62 (m, 1H, ^3J = 8.4 Hz, ^3J = 7.0 Hz, H-2), 7.69-7.80 (m, 3H, ^3J = 8.4 Hz, ^3J = 7.0 Hz, H-9, H-3 and H-10), 8.04-8.07 (dd, 1H, ^3J = 8.4 Hz, H-4), 8.12-8.14 (dd, 1H, ^3J = 8.4Hz, H-11), 8.37-8.39 (dd, 1H, ^3J = 8.4 Hz, H-1), 8.45-8.48 (dd, 1H, ^3J = 8.4 Hz, H-8), 8.93 (s, 1H, H-13). *Anal.* Calcd for $C_{24}H_{20}N_2S_2$: C 71.97, H 5.03, N 6.99. Found: C 71.87, H 5.23, N 7.01.

6,12-Dicyclohexylthioquinanthrene (**1e**). This compound was obtained as bright yellow plates (xylene), mp. 130-132°C. ^{1}H nmr, δ: 1.38-2.06 (m, 20H, 10 x CH_2), 3.58–3.68 (m, 2H, 2x CH), 7.59-7.64 (m, 2H, ^3J = 8.4 Hz, ^3J = 7.0 Hz, H-2 and H-9), 7.69-7.74 (m, 2H, ^3J = 8.4 Hz, ^3J = 7.0 Hz, H-3 and H-10), 8.05-8.07 (dd, 2H, ^3J = 8.4 Hz, H-4 and H-11), 8.45-8.48 (dd, 2H, ^3J = 8.4 Hz, H-1 and H-8). *Anal.* Calcd for $C_{30}H_{30}N_2S_2$: C 74.65, H 6.26, N 5.80. Found: C 74.68, H 6.34, N 5.88.

6-Isopropyl-12-cyclohexyl-thioquinanthrene (**1f**). This compound was obtained as bright yellow plates (xylene), mp. 164-165°C. ^{1}H nmr, δ: 1.34-2.06 (m, 10 H, 5 x CH_2), 1.47-1.48 (d, 6H, ^3J = 6.8 Hz, 2 x CH_3,), 3.59-3.65 (m, 1H, CH in cyclohexyl ring), 4.00 (septet, 1H, ^3J = 6.8 Hz, CH of isopropyl group), 7.58-7.63 (m, 2H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-2 and H-9), 7.69-7.73 (m, 2H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-3 and H-10), 8.06–8.08 (m, 2H, ^3J = 8.4 Hz, H-4 and H-11), 8.45-8.48 (m, 2H, ^3J = 8.4 Hz, H-1 and H-8). *Anal.* Calcd for $C_{27}H_{26}N_2S_2$: C 73.26, H 5.92, N 6.33, S, 14.49. Found: C 73.18, H 5.84, N 5.81.

6-Isopropylisothioquinanthrene (**2b**). This compound was obtained as bright yellow plates (xylene), mp.188-191°C. ^{1}H nmr, δ: [δ_C for carbons from single bond and / long-range proton-carbon correlations]: 1.47 [(d, 6H, ^3J = 6.8 Hz, 2 x CH_3); 21.6 (CH_3) / 34.2 (CH), 163.6 (C-6)], 3.90 [(septet, 1H, ^3J = 6.8 Hz, CH); 34.0 (CH) / 163.6 (C-6), 129.1 (C-6a)], 7.60 [(ddd, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, ^4J = 1.3 Hz, H-2); 126.9 (C-2) / 126.2 (C-14b), 129.7 (C-4)], 7.68 [(ddd, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, ^4J = 1.3 Hz, H-12); 127.9 (C-12) / 130.0 (C-10), 127.1 (C-13a)], 7.70 [(ddd, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, H-3); 129.7 (C-3) / 123.5 (C-1), 129.7 (C-4)], 7.75 [(ddd, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, H-11); 130.0 (C-11) / 123.7 (C-13), 147.1 (C-9a)], 8.08 [(dd, 1H, ^3J = 8.4 Hz, ^4J = 1.3 Hz, H-4); 129.7 (C-4) / 126.9 (C-2), 126.2 (C-14b)], 8.13 [(dd, 1H, ^3J = 8.4 Hz, ^4J = 1.3 Hz, H-10); 130.0 (C-10) / 130.0 (C-11), 127.0 (C-13a)], 8.48 [(m, 1H, H-1); 123.5 (C-1) / 141.3 (C-14a), 146.6 (C-4a), 129.7 (C-3)], 8.50 [(m, 1H, H-13); 123.7 (C-13) / 143.0 (C-13b), 127.9 (C-12), 147.1 (C-9a)], 8.93 [(m, 1H, H-8); 148.3 (C-8) / 129.6 (C-7a), 147.1 (C-9a), 143 (C-13b)]. *Anal.* Calcd for $C_{21}H_{16}N_2S_2$: C 69.97, H 4.44, N 7.77. Found: C 69.91, H 4.36, N 7.87.

6,8-Diisopropylisothioquinanthrene (**2c**). This compound was obtained as bright yellow plates (xylene), mp. 169-171°C. ^{1}H nmr, δ: 1.47-1.48 (d, 12H, ^3J = 6.8 Hz, 4 x CH_3), 3.95-4.04 (septet, 2H, ^3J = 6.8 Hz, 2 x CH), 7.59-7.62 (m, 2H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-2 and H-12), 7.69-7.73 (m, 2H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-3 and H-11), 8.06-8.08 (dd, 2H, ^3J = 8.4 Hz, H-4 and H-10), 8,50-8.52 (dd, 2H, ^3J = 8.3 Hz, H-1 and H-13). *Anal.* Calcd for $C_{24}H_{22}N_2S_2$: C 71.61, H 5.51, N 6.96. Found: C 71.60, H 5.59, N 6.91.

6-Cyclohexylisothioquinanthrene (**2d**). This compound was obtained as bright yellow plates (xylene), mp. 142-143°C. ^{1}H nmr, δ: 1.23-2.10 (m, 10H, 5 x CH_2), 3.62-3.41 (m, 1H, CH),

7.62-7.67 (m, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-2), 7.68-7.78 (m, 3H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-3, H-11 and H-12), 8.05-8.07 (dd, 1H, ^3J = 8.4 Hz, H-4), 8.11-8.14 (dd, 1H, ^3J = 8.4 Hz, H-10), 8.47-8.49 (dd, 1H, ^3J = 8.4 Hz, H-1), 8.49-8.51 (dd, 1H, ^3J = 8.4 Hz, H-13), 8.95 (s, 1H, H-8). *Anal*. Calcd for $C_{24}H_{20}N_2S_2$: C 71.97, H 5.03, N 6.99. Found*:* C 71.93, H 5.04, N 6.96.

6,12-Dicyclohexylisothioquinanthrene (**2e**). This compound was obtained as bright yellow plates (xylene), mp. 197-199°C. ^{1}H nmr, δ: 1.23-2.10 (m, 20H, 10 x CH_2), 3.52-3.65 (m, 2H, 2 x CH), 7.60-7.72 (m, 2H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-2 and H-12), 7.60-7.72 (m, 2H, , ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-3 and H-11), 8.49-8.51 (dd, 2H, ^3J = 8.4 Hz, H-4 and H-10), 8.05-8.07 (dd, 2H, ^3J = 8.4 Hz, H-1 and H-13). *Anal*. Calcd for $C_{30}H_{30}N_2S_2$: C 74.65, H 6.26, N 5.80. Found*:* C 74.44, H 6.21, N 5.76.

2-Isopropyl-3,4-dimethylthioquinoline (**3b**). This compound was obtained as an oil. ^{1}H nmr, δ: 1.38-1.39 (d, 6H, ^3J = 6.8 Hz, 2 x CH_3), 2.48 (s, 3H, SCH_3), 2.55 (s, 3H, SCH_3), 4.13-4.20 (septet, 1H, ^3J = 6.8 Hz, CH), 7.52-7.56 (m, 1H, ^3J = 8.3 Hz, ^3J = 7.0 Hz, H-6), 7.66-7.70 (m, 1H, ^3J = 8.4 Hz, ^3J = 7.0 Hz, H-7), 8.03-8.05 (m, 1H, ^3J = 8.4 Hz, H-8), 8.47-8.49 (m, 1H, ^3J = 8.3 Hz, H-5). *Anal*. Calcd for $C_{14}H_{17}NS_2$: C 63.84, H 6.50, N 5.32. Found*:* C 63.90, H 6.80, N 5.42.

2-Cyclohexyl-3,4-dimethylthioquinoline (**3c**). This compound was obtained as an oil. ^{1}H nmr, δ: 1.36-1.91 (m, 10H, 5 x CH_2), 2.48 (s, 3H, SCH_3), 2.54 (s, 3H, SCH_3), 3.75-3.79 (m, 1H, CH), 7.51-7.55 (m, 1H, ^3J = 8.3 Hz, ^3J = 6.9 Hz, H-6), 7.65-7.69 (m, 1H, ^3J = 8.3 Hz, ^3J = 6.9 Hz, H-7), 8.02-8.04 (m, 1H, ^3J = 8.3 Hz, H-8), 8.46-8.49 (m, 1H, ^3J = 8.2 Hz, H-5). *Anal*. Calcd for $C_{17}H_{21}NS_2$: C 67.28, H 6.97, N 4.62. Found*:* C 67.34, H 6.99, N 4.59.

5-Isopropyl-2,3-dihydro-1,4-dithiino[5,6-*c*]quinoline (**4b**). This compound was obtained as an oil ^{1}H nmr, δ: 1.35-1.37 (d, 6H, ^3J = 6.4 Hz, 2 x CH_3) 3.30-3.47 (s, 4H, 2 x SCH_2), 3.55-3.61 (septet, 1H, ^3J = 6.4 Hz, CH), 7.44-7.47 (m, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-9), 7.56-7.58 (m, 1H, ^3J = 8.3 Hz, ^3J = 6.9 Hz, H-8), 7.94-7.96 (dd, 1H, ^3J = 8.4 Hz, H-7), 8,00-8.03 (dd, 1H, ^3J = 8.4 Hz, H-10). *Anal*. Calcd for $C_{14}H_{15}NS_2$: C 64.33, H 5.78, N 5.36. Found*:* C 64.43, H 5.65, N 5.48.

5-Cyclohexyl-2,3-dihydro-1,4-dithiino[5,6-*c*]quinoline (**4c**). This compound was obtained as an oil. ^{1}H nmr, δ: 1.30-1.91 (m, 10H, 5 x CH_2), 3.17-3.23 (m, 1H, CH), 3.29-3.46 (s, 4H, 2 x SCH_2), 7.42-7.46 (m, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-9), 7.55-7.59 (m, 1H, ^3J = 8.4 Hz, ^3J = 6.9 Hz, H-8), 7.93-7.94 (d, 1H, ^3J = 8.4 Hz, H-7), 7.99-8.02 (d, 1H, ^3J = 8.4 Hz, H-10). *Anal*. Calcd for $C_{17}H_{19}NS_2$: C 67.73, H 6.35, N 4.65. Found*:* C 67.70, H 6.46, N 4.61.

Reactions isopropyl derivatives 1b,c and 2b,c with potassium methoxide. A mixture of quinolinyl sulfide (1 mmol), potassium methoxide (0.21 g, 3 mmol) and dry DMSO (10 mL) was stirred at 70 °C for 0.5 h. It was then poured into 20 mL of 15 % aq. sodium hydroxide, and filtered. Methyl iodide (0.08 mL, 1.2 mmol) was added to the filtrate with intensive stirring. Stirring was continued for 15 min and the mixture was extracted with $CHCl_3$ (3 x 10 mL). Combined extracts were washed with water, dried ($MgSO_4$), filtered and evaporated to dryness to give crude solid product. It was triturated with cold ethanol (0.5 mL) and filtered, and the solid was recrystallized from ethanol.

2'-Isopropyl-4-methoxy-3'-methylthio-3,4'-diquinolinyl sulfide (**6a**). This compound was obtained as yellow needless (ethanol), mp 135-137°C; ^{1}H nmr, δ: [δ_C for carbons from single bond and / long range proton-carbon correlation]: 1.41 [(d, 6H, ^3J = 6.8 Hz, 2 x CH_3); 22.9 (CH_3) / 169.8 (C-2')], 2.41 [(s, 3H, SCH_3); 21.2 (SCH_3) / 136.3 (C-3')], 4.16 [(m, 1H, ^3J = 6.8 Hz, CH); 34.5 (CH) / 22.9 (CH_3), 169.8 (C-2'), 136.3 (C-3')], 4.19 [(s, 3H, OCH_3); 62.2 (OCH_3) / 159.9 (C-4)], 7.39 [(m, 1H, ^3J = 8.3 Hz, ^3J = 6.7 Hz, H-6'); 127.4 (C-6') / 122.2 (C-4a'), 130.4 (C-8')], 7.56 [(m, 1H, ^3J = 8.3 Hz, ^3J = 6.7 Hz, H-6); 127.4 (C-6) / 123.9 (C-4a), 130.4 (C-8)], 7.64 [(m, 1H, ^3J = 8.3 Hz, ^3J = 6.7 Hz, H-7'); 129.7 (C-7') / 126.6 (C-5'), 148.3 (C-8a')], 7.64 [(m, 1H, ^3J = 8.3 Hz, ^3J = 6.7 Hz, H-7); 129.9 (C-7) / 121.8 (C-5), 148.8 (C-8a)], 7.95 [(m, 1H, ^3J = 8.3 Hz, H-8'); 130.4 (C-8') / 122.2 (C-4a'), 127.4 (C-6')], 8.08 [(m, 1H, ^3J = 8.3 Hz, H-8); 130.4 (C-8) / 123.9 (C-4a), 127.4 (C-6)], 8.06 [(m, 1H, ^3J = 8.4 Hz, H-5); 121.8 (C-5) / 129.9 (C-7), 159.9 (C-4), 148.8 (C-8a)], 8.10 [(m, 1H, H2); 151.2 (C-2) / 159.9 (C-4)], 8.26 [(m, 1H, ^3J = 8.4 Hz, H-5'); 126.6 (C-5') / 129.7 (C-7'), 128.8 (C-4'), 148.3 (C-8a')], there is no correlations for C-3 (146.6). *Anal*. Calcd. for $C_{23}H_{22}N_2OS_2$: C 67.95, H 5.45, N 6.89. Found C 67.90, H 5.45, N 6.67.

2,2'-Diisopropyl-4-methoxy-3'-methylthio-3,4'-diquinolinyl sulfide (**6b**). This compound was obtained as yellow needless (ethanol), mp 117-118 °C; ^{1}H nmr, δ: 1.32-1.33 (d, 6H, CH_3, ^3J = 6.8 Hz), 1.38-1.42 (d, 6H, CH_3, ^3J = 6.8 Hz), 2.16 (s, 3H, SCH_3), 3.66 (s, 3H, OCH_3), 4.15-4.26 (m, 2H, CH), 7.38-7.40 (m, 1H, ^3J = 8.3 Hz, ^3J = 6.7 Hz, H-6), 7.47-7.51 (m, 1H, ^3J = 8.3 Hz, ^3J = 6.7 Hz, H-6'), 7.59-7.67 (m, 2H, ^3J = 8.3 Hz, ^3J = 6.7 Hz, H-7 and H-7'), 7.67-7.76 (dd, 1H, ^3J = 8.3 Hz, H-8'), 8.03-8.06 (m, 2H, ^3J = 8.4 Hz, H-5 and H-8), 8.26-8.32 (dd, 1H, ^3J = 8.4 Hz, H-5'). *Anal*. Calcd. for $C_{26}H_{28}N_2OS_2$: C 69.61, H 6.29, N 6.24. Found C 69.40, H 6.22, N 6.11.

2'-Isopropyl-4-methoxy-4'-methylthio-3,3'-diquinolinyl sulfide (**7a**). This compound was obtained as yellow needless (ethanol), mp 80-81°C; ^{1}H nmr, δ: [δ_C for carbons from single bond and / long range proton-carbon correlation]: 1.33 [(d, 6H, ^3J = 6.8 Hz, 2 x CH_3), 22.7 (CH_3) / 169.3 (C-2')]; 2.42 [(s, 3H, SCH_3), 20.8 (SCH_3) / 153.5 (C-4')], 4.04 [(m, 1H, ^3J = 6.8 Hz, CH); CH (34.7) / CH_3 (22.4), C-2'(169.3), C-3'(129.6)], 4.20 [(s, 3H, OCH_3); OCH_3 (61.8) / C-4 (159.3)], 7.45 [(m, 1H, ^3J = 8.4 Hz, ^3J = 6.8 Hz, H-7'); 130.8 (C-7') / 127.1 (C-5'), 130.5 (C-8a')], 7.56 [(m, 1H, ^3J = 8.3 Hz, ^3J = 6.8 Hz, H-6); 127.2 (C-6) / 123.3 (C-4a), 130.0 (C-8)], 7.58 [(m, 1H, ^3J = 8.3 Hz, ^3J = 6.8 Hz, H-6'); 127.4 (C-6') / 123.9 (C-4a'), 130.5 (C-8')], 7.64 [(m, 1H, ^3J = 8.4 Hz, ^3J = 6.8 Hz, H-7); 129.4 (C-7) / 121.7 (C-5), 148.6 (C-8a)], 7.98 [(m, 1H, ^3J = 8.3 Hz, H-8); 130.0 (C-8) / 123.3 (C-4a), 127.2 (C-6)], 8.07 [(m, 1H, ^3J = 8.3 Hz, H-5'); 150.1 (C-2) / 159.3 (C-4)], 8.07 [(m, 1H, ^3J = 8.3 Hz, H-5); 121.7 (C-5) / 129.4 (C-7), 159.3 (C-4), 148.6 (C-8a)], 8.10 [(m, 1H, ^3J = 8.3 Hz, H-8'); 130.5 (C-8') / 123.9 (C-4a'), 127.4 (C-6')], 8.44 [(m, 1H, ^3J = 8.3 Hz, H-5'); 127.1 (C-5') / 130.8 (C-7'), 153.5 (C-4'), 148.6 148.6 (C-8a')]. *Anal*. Calcd. for $C_{23}H_{22}N_2OS_2$: C 67.95, H 5.45, N 6.89. Found C 67.90, H 5.34, N 6.67.

2,2'-Diisopropyl-4-methoxy-4'-methylthio-3,3'-diquinolinyl sulfide (**7b**). This compound was obtained as yellow needless (ethanol), mp 114-116 °C (ethanol). ^{1}H nmr, δ: 1.32-1.34 (d, 6H, ^3J = 6.8 Hz, CH_3), 1.40-1.42 (d, 6H, ^3J = 6.8 Hz, CH_3), 2.16 (s, 3H, SCH_3), 3.66 (s, 3H, OCH_3), 4.15-4.21 (septet, 1H, ^3J = 6.8 Hz, CH), 4.23-4.29 (septet, 1H, ^3J = 6.8 Hz, CH), 7.36-7.40 (m, 1H, ^3J = 8.4 Hz, ^3J = 6.7 Hz, H-6), 7.47-7.51 (m, 1H, ^3J = 8.3 Hz, ^3J = 6.8 Hz, H-6'), 7.59-7.63 (m, 1H, ^3J = 8.3 Hz, ^3J = 6.7 Hz, H-7), 7.63-7.67 (m, 1H, ^3J = 8.3 Hz, ^3J = 6.7 Hz, H-7'), 7.74-7.76 (dd, 1H, ^3J = 8.3 Hz, H-8), 8.02-8.04 (dd, 1H, ^3J = 8.3 Hz, H-5'), 8.04-8.06 (m, 1H, ^3J = 8.3 Hz, H-8'), 8.26-8.28 (dd, 1H, ^3J = 8.3 Hz, H-5'). *Anal*. Calcd. for

$C_{26}H_{28}N_2OS_2$: C 69.61, H 6.29, N 6.24. Found C 69.90, H 6.28, N 6.11.

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