

Chemistry of Substituted Quinolinones. Part VI.[†] Synthesis and Nucleophilic Reactions of 4-Chloro-8-methylquinolin-2(1*H*)-one and its Thione Analogue

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[†] For part V see reference [1].

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Abstract: The synthesis of 4-chloro-8-methylquinolin-2(1*H*)-one and its thione analogue is described. Some nucleophilic substitution reactions of the 4-chloro group were carried out to get new 4-substituted 2-quinolinones and quinolinethiones, such as 4-sulfanyl, hydrazino, azido and amino derivatives, which are of important synthetic use. The structure of the new compounds was established by their elemental analysis, IR and ¹H-NMR spectra. Also the mass fragmentation pattern of some products is discussed.

Keywords: quinolinone, quinolinethione, nucleophilic substitution, thiol-thione tautomerism, mass fragmentation.

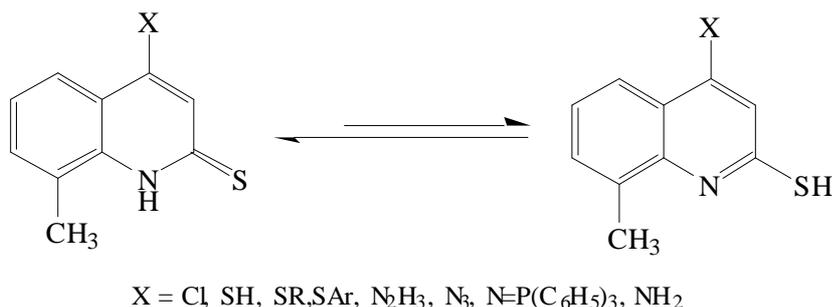
Introduction

In connection with our previous studies on nucleophilic reactions with chloroquinolines [1-3], we have synthesized 4-chloro-8-methylquinolin-2(1*H*)-one and its thio-analogue to investigate their reactivity towards certain nucleophilic substitution reactions at position-4. Thiation, hydrazination, azidation and amination reactions led to formation of a series of 4-substituted quinolin-2-ones (or 2-

thiones). Since the thiation of quinolinones with Lawesson reagent or phosphorous pentasulfide is often poor in yield and leads to 2- and/or 4-thiated products [4], this work explores a facile and simple thiation using the known reaction of thiourea with haloheteroarenes [5,6].

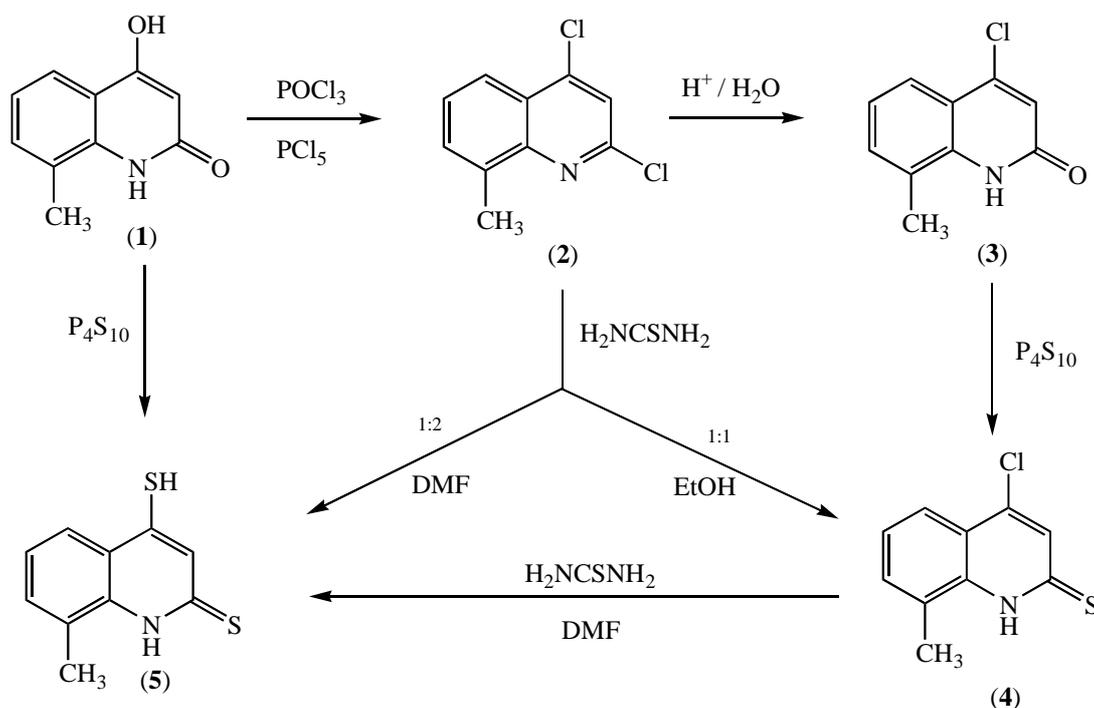
Results and Discussion

Chlorination of 4-hydroxy-8-methylquinolin-2(1*H*)-one (**1**) [7] with a mixture of phosphoryl chloride and phosphorus pentachloride afforded 2,4-dichloro-8-methylquinoline (**2**) [1]. Acid hydrolysis of dichloroquinoline **2**, using dilute dichloroacetic acid, furnished 4-chloro-8-methylquinolin-2(1*H*)-one (**3**). Heating of compound **3** with phosphorus pentasulfide gave its thio-isomer 4-chloro-8-methylquinoline-2(1*H*)-thione (**4**), in a relatively low yield. The same compound **4** was prepared in fair yield when dichloroquinoline **2** was reacted with a 1:1 molar ratio of thiourea in boiling ethanol. The ¹H-NMR spectrum of compound **4** in DMSO revealed the existence of a thiolactam-thiolactim equilibrium. Thus, the acidic proton (deuterium exchangeable) is fractionally present at two chemical shifts. We found that the thiolactam tautomer is predominant (thione : thiol ratio 3 : 2). This behaviour is similar to the known behaviour of most thiolactams and lactams, in particular 2-quinolinones [8].



Thiolactam-thiolactim Tautomerism of 4-Substituted Quinoline-2(1*H*)-thiones

The mass fragmentation pattern showed the stability of the molecular ion (*m/e* 209.5), which appeared as the base peak (*cf.* Chart 1). Increasing of the molar ratio of thiourea and using boiling DMF as the solvent led to formation of 8-methyl-4-sulfanylquinoline-2(1*H*)-thione (**5**). Application of these conditions to the reaction of thiourea with compound **4** also gave compound **5**. The mass fragmentation pattern of compound **5** also showed the molecular ion (*m/e* 207) as the base peak (*cf.* Chart 2). The direct thiation of hydroxyquinolinone **1** with phosphorus pentasulfide was tested and the yield again is found to be much poorer. Building on the reaction yield and product purity we can conclude that direct thiation of quinolinones **1** and **3** using phosphorus pentasulfide is disfavored, when it is compared with the described thiation of chloroquinolines (Scheme 1).



Scheme 1.

4-Chloroquinolinone **3** was used as a precursor for obtaining some new 4-substituted quinolinones. Thus, thiation of compound **3** with thiourea was carried out under fusion conditions to give 8-methyl-4-sulfanylquinolin-2(1H)-one (**6**). It was found that compound **6** is selectively *S*-alkylated, using alkyl iodides; namely ethyl iodide and butyl iodide, in the presence of a base catalyst, leading to 4-alkylthio-8-methylquinolinones **7a** and **7b**, respectively. Alternatively, compounds **7a** and **7b** were also obtained when chloroquinolinone **3** was treated with the appropriate alkanethiol in the presence of sodium ethoxide. Similarly, 8-methyl-4-phenylthioquinolin-2(1H)-one (**7c**) was prepared from compound **3** and thiophenol. Hydrazination of each of 4-chloroquinolinone **3**, 4-ethylthioquinolinone **7a** and/or 4-tosyloxyquinolinone **9** resulted in the same product, which was characterized as 4-hydrazino-8-methylquinolin-2(1H)-one (**8**). The tosylate **9** was prepared from reaction of 4-hydroxyquinolinone **1** with toluene-4-sulfonyl chloride in pyridine. Although the yield of hydrazinoquinolinone **8** is apparently the lowest (53 %), we can say that use of tosylate **9**, as a reagent for preparing hydrazinoquinolinone **8**, is much more favorable as a synthetic approach. This is obvious if we compare this obtained yield with the overall yield starting from preparation of dichloroquinoline **2** (overall yield = 36.8 %) (Scheme 2). In a similar fashion both chloroquinolinone **3** and tosylate **9** were subjected to azidation reaction with sodium azide in DMF, furnishing 4-azido-8-methylquinolin-2(1H)-one (**10**). The compound **10** was also obtained in a much higher yield and purity, by action of nitrous acid on the hydrazinoquinolinone **8**. *Staudinger* reaction [9] was employed to reduce the azide **8** to its corresponding amine. The advantage of this method goes back to its controlled conversion of azide function to phosphazene, which subsequently could be hydrolyzed smoothly to the desired amine. Other reduction methods like catalytic hydrogenation are more expensive and could lead to several by-

products especially when other sensitive functions are present in the substrate [10]. Thus, treatment of the azide **10** with triphenylphosphine afforded the phosphazene **11**, which upon hydrolysis, using dilute hydrochloric acid, gave 4-amino-8-methylquinolin-2(1*H*)-one (**12**) [1] (Scheme 2).

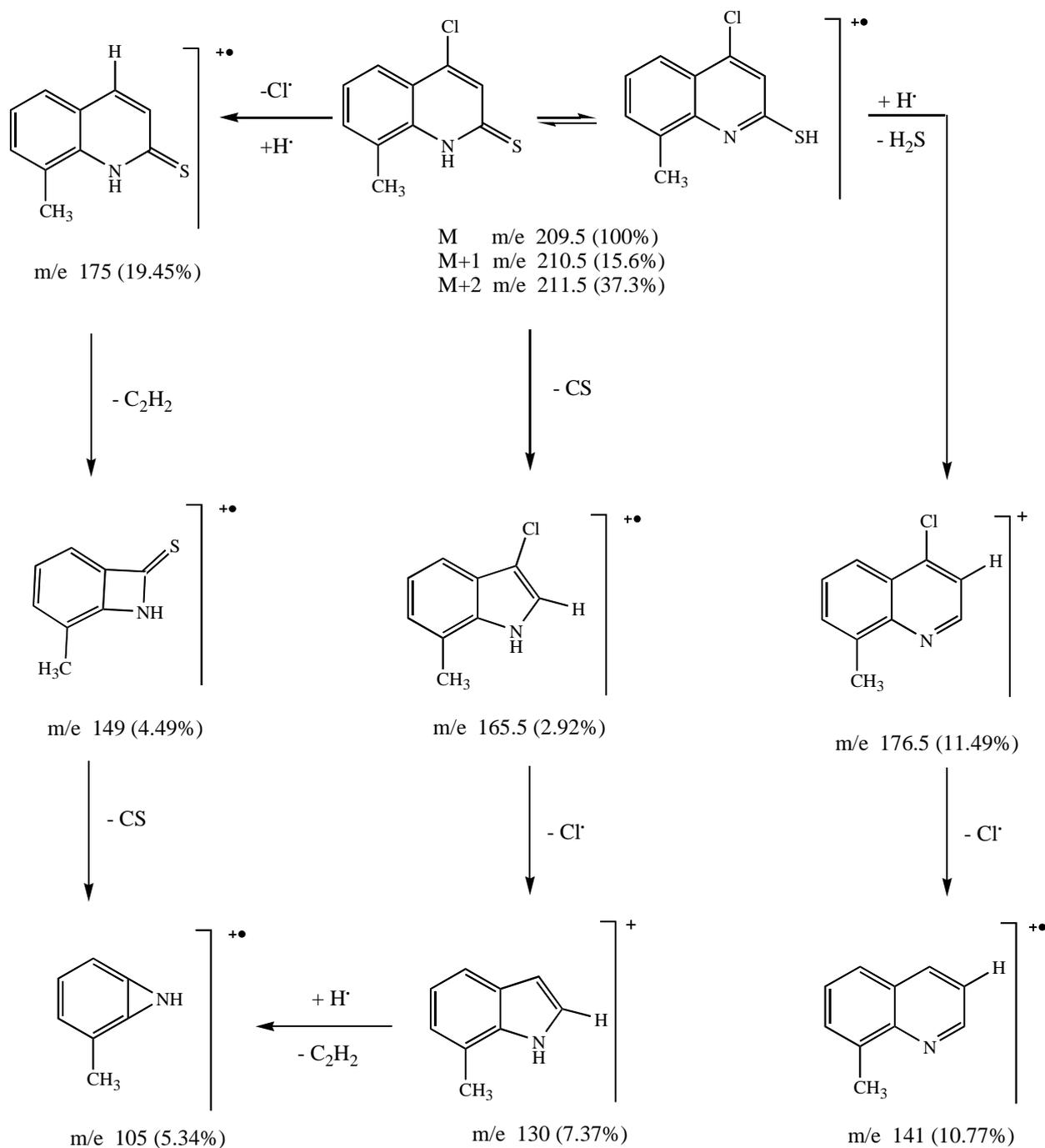


Chart 1. Mass Fragmentation Pattern of Compound **4**

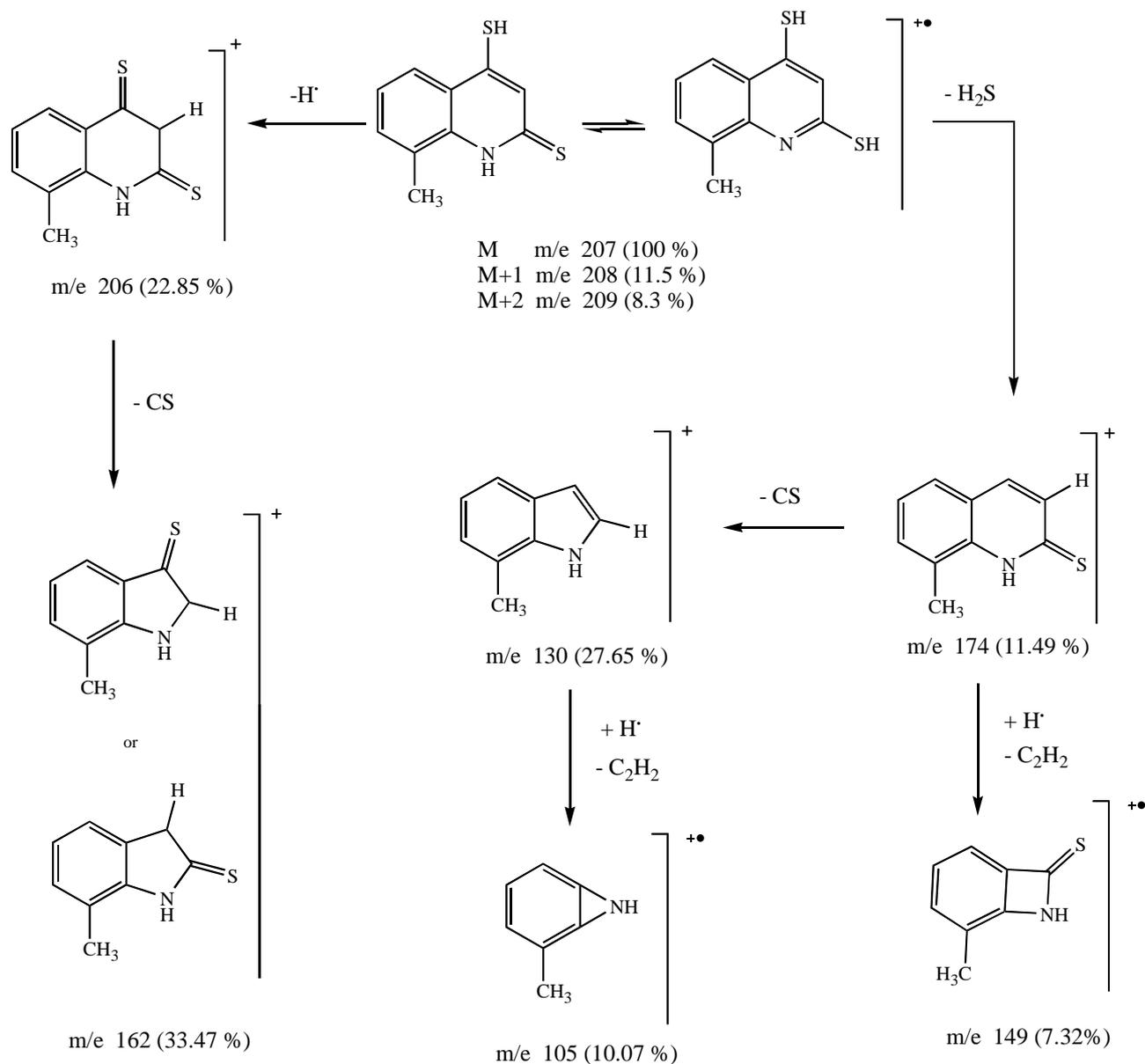
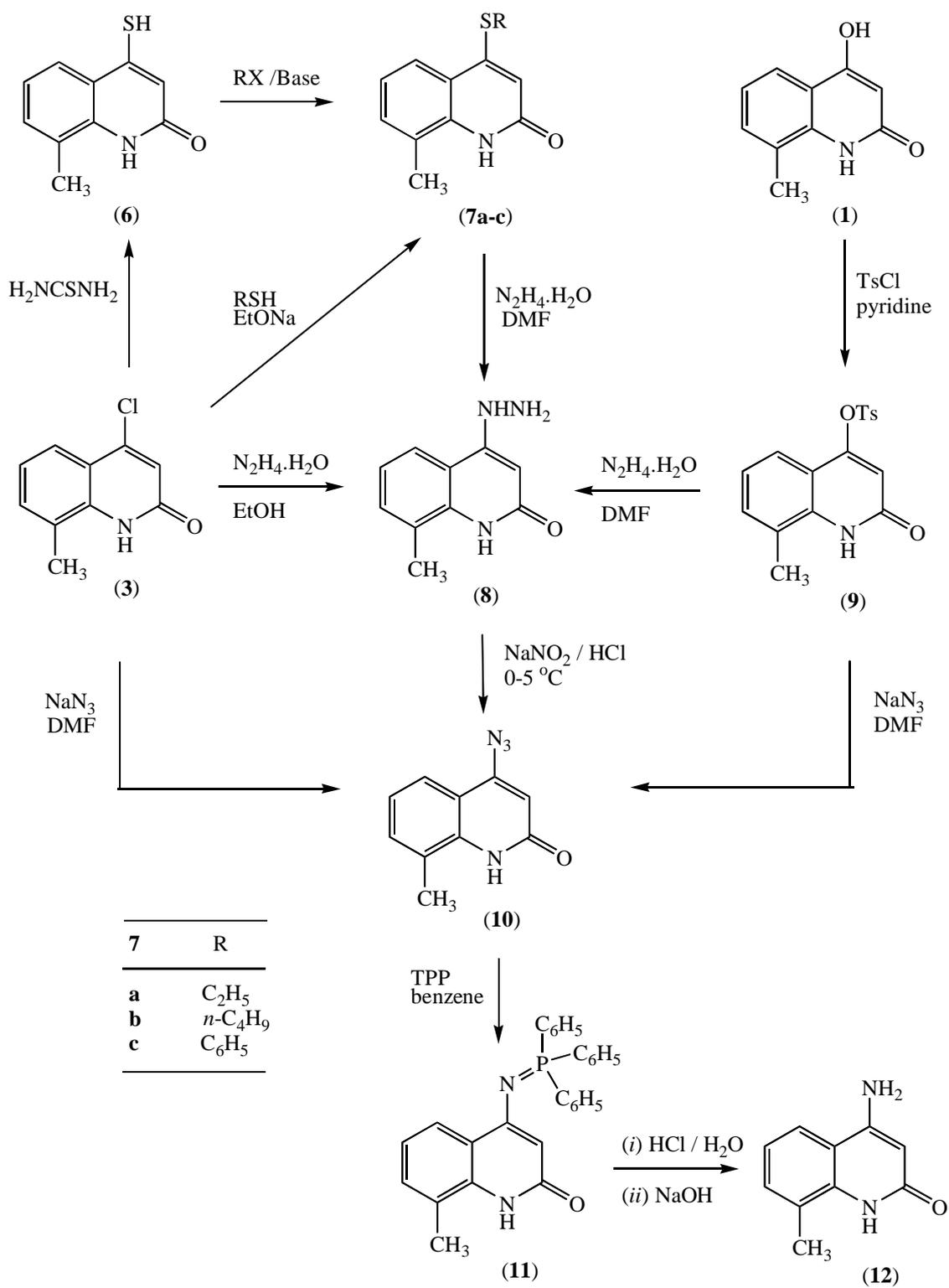
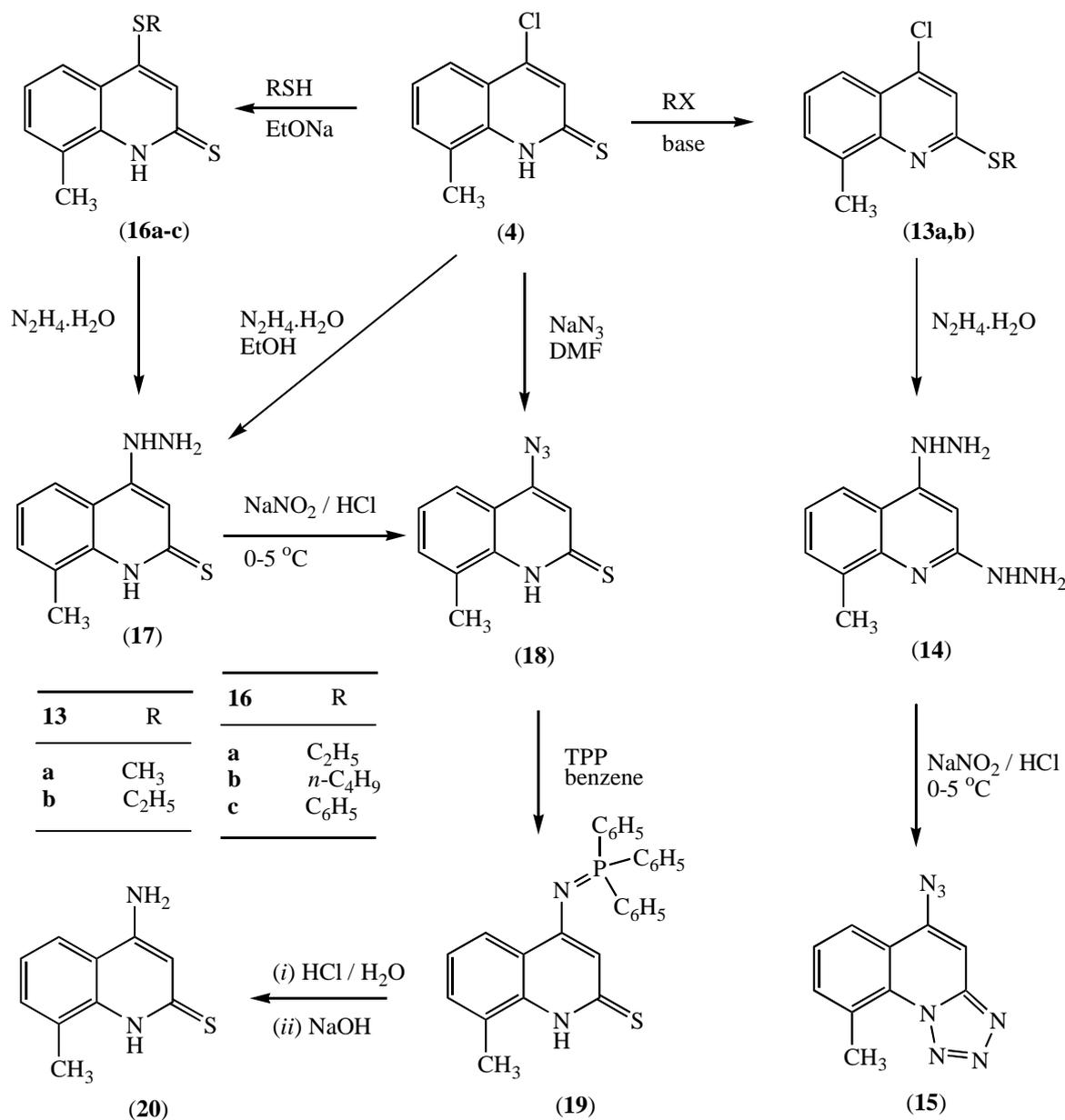


Chart 2. Mass Fragmentation Pattern of Compound 5

4-Chloroquinoline-2-thione **4** was subjected to alkylation reactions, using dimethyl sulfate and/or ethyl iodide, resulting in 2-alkylthio-4-chloro-8-methylquinolines **13a** and **13b**. Interestingly compound **13a** (R = C₂H₅) was hydrazinated at both the 2- and 4- sites to give 2,4-dihydrazino-8-methylquinoline (**14**). Hydrazination of dichloroquinoline **2** revealed the inactivity of position-2 towards this nucleophilic displacement. This shows that the presence of ethylthio group instead of chloro group at position-2 enabled the hydrazinolysis reaction i.e. the leaving group plays an important role in such substitution reactions at position-2. The structure of dihydrazinoquinoline **14** was established by its reaction with nitrous acid which led to 5-azido-8-methyltetrazolo[1,5-*a*]quinoline (**15**) [1] (Scheme 3).



Scheme 2.



Scheme 3.

Reaction of 4-chloroquinolinethione **4** with certain thiols, *viz.* ethanethiol, butanethiol and thiophenol, gave the corresponding 4-alkyl(or phenyl)thio-8-methylquinolin-2(1H)-thiones **16a-c**. Hydrazination of the chloroquinolinethione **4** or the sulfide **16a** (R = C₂H₅) led to the same product; 4-hydrazino-8-methylquinolin-2(1H)-thione (**17**). The structure of compound **17** was elucidated *via* the mass fragmentation pattern (Chart 3). Reaction of compound **4** with sodium azide furnished 4-azido-8-methylquinolin-2(1H)-thione (**18**), which was also prepared by reacting the hydrazinoquinolinethione with nitrous acid. 4-Amino-8-methylquinolin-2(1H)-thione (**20**) was prepared in a similar manner to obtain aminoquinolinone **12**. Thus, the azide **18** was reacted with triphenylphosphine in boiling

benzene to give the phosphazene **19** which was subjected to acid hydrolysis furnishing the desired 4-aminoquinoline-2-thione **20** (Scheme 3).

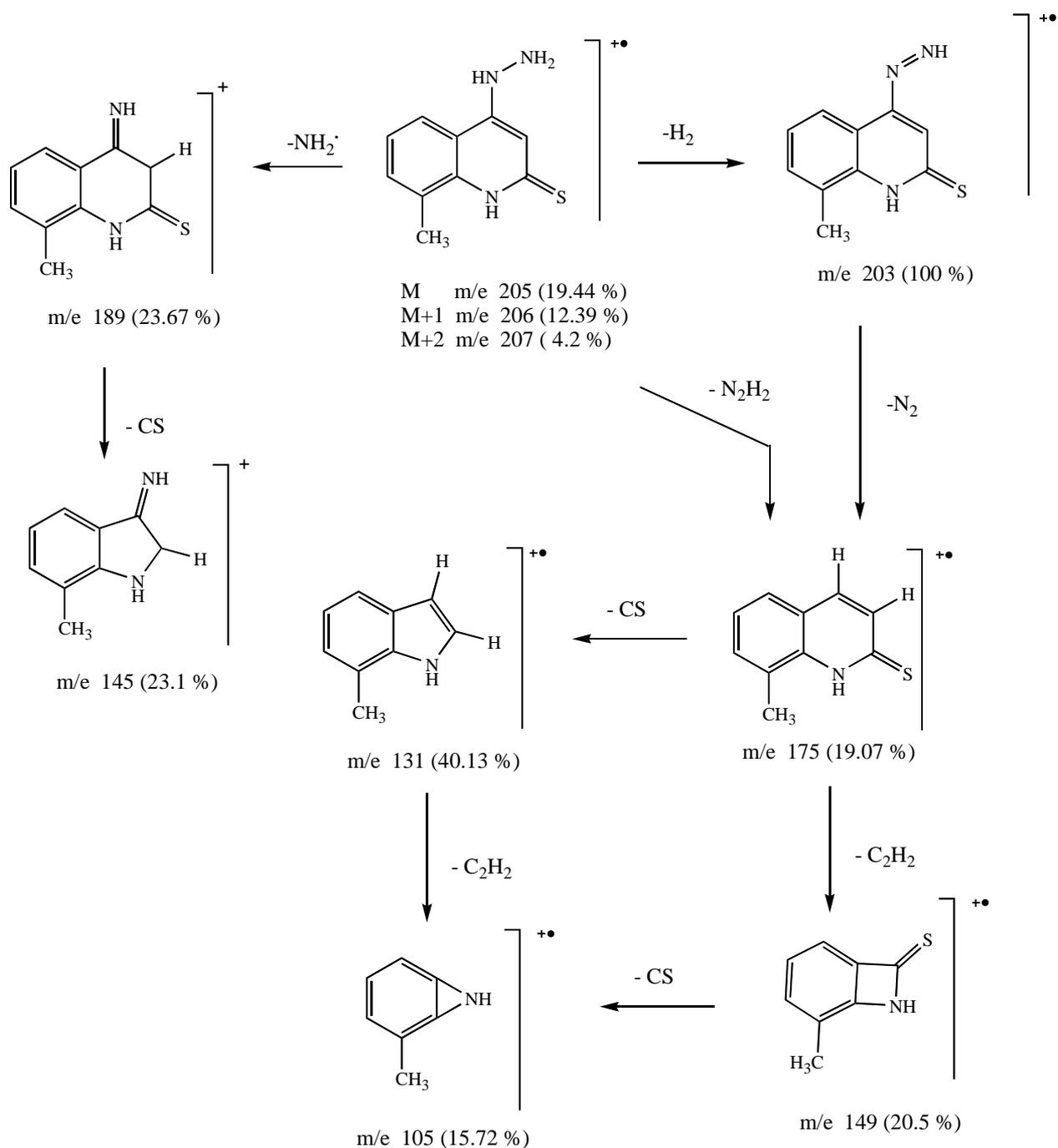


Chart 3. Mass Fragmentation Pattern of Compound **17**

Experimental

General

Melting points were determined on a Gallenkamp apparatus and are uncorrected. IR spectra were recorded on a Perkin-Elmer FT-IR 1650 spectrophotometer using KBr disks. ¹H-NMR spectra were measured in CDCl₃ or DMSO-d₆ on Jeol FX-90 (90 MHz) and Jeol EX-270 (270 MHz) spectrometers, using TMS as an internal standard. Mass spectra were obtained on a HP MS-5988 (Electron energy 70 eV). Elemental analyses were performed at Cairo University Microanalytical Centre. Compounds **1** and **2** were prepared as previously described in the literature (References [7] and [1], respectively).

4-Chloro-8-methylquinolin-2(1H)-one (**3**)

A solution of dichloroquinoline **2** (2.12 g, 10 mmol) in dilute dichloroacetic acid (50 mL, 90 %) was heated under reflux for 1h. The clear solution was then poured onto ice-cold water and the precipitate that formed was collected by filtration and crystallized.

4-Chloro-8-methylquinoline-2(1H)-thione (**4**)

Method A

A mixture of dichloroquinoline **2** (2.12 g, 10 mmol) and thiourea (0.76 g, 10 mmol), in absolute ethanol (30 mL), was refluxed on a boiling water-bath for 4h. The reaction mixture was then left to cool and poured onto 2M sodium hydroxide solution (50 mL), then filtered off and acidified using 2M hydrochloric acid (50 mL). The yellow deposits thus formed were collected by filtration, washed with water and crystallized.

Method B

To a solution of chloroquinolinone **3** (1.94 g, 10 mmol) in *o*-xylene (100 mL), phosphorus pentasulfide (4.44 g, 10 mmol) was added and the mixture was heated under reflux for 24 h. The solvent was removed by evaporation and the residue extracted several times with chloroform (4 x 25 mL). The extracts were washed with water and dried over anhydrous calcium chloride. The solvent was removed in *vacuo* and the residue was crystallized to give quinolinethione **4** (identified by its m.p., mixed m.p. and spectral data).

8-Methyl-4-sulfanylquinoline-2(1H)-thione (**5**)

Method A

A mixture of dichloroquinoline **2** (2.12 g, 10 mmol) and thiourea (2.28 g, 30 mmol), in DMF (30 mL), was heated under reflux for 4h. Afterwards the reaction mixture was poured onto cold water and

the solid so obtained was dissolved in 0.5 M sodium hydroxide solution (100 mL) and filtered off to remove insoluble materials. The alkaline solution was precipitated using 1 M hydrochloric acid (60 mL) to give yellow precipitates, which were collected by filtration and crystallized.

Method B

To a solution of hydroxyquinolinone **1** (1.75 g, 10 mmol) in *o*-xylene (100 mL), phosphorus pentasulfide (8.88 g, 20 mmol) was added and the reaction was processed as described for compound **4**, *Method A*.

Method C

Using the same method *B* that used for obtaining compound **4**, compound **5** was obtained from equimolar amounts (10 mmol) of chloroquinolinethione **4** and thiourea in boiling DMF (30 mL).

8-Methyl-4-sulfanylquinolin-2(1*H*)-one (**6**)

A mixture of 4-chloroquinolinone **3** (1.94 g, 10 mmol) and thiourea (1.52 g, 20 mmol) was heated in an oil-bath at 170–190 °C for 1h. The reaction mixture was cooled and treated with aqueous solution of sodium hydroxide (50 mL, 0.5 M) and the solution so obtained was filtered from insoluble materials. The clear filtrate was acidified by hydrochloric acid (50 mL, 0.5 M). The yellow precipitate that separated was filtered off and crystallized.

4-Alkyl (or aryl)thio-8-methylquinolin-2(1*H*)-ones **7a-7c**

Method A

A mixture of chloroquinolinone **3** (1.94 g, 10 mmol) and the appropriate thiol: ethanethiol, butanethiol or thiophenol (15 mmol) was treated with sodium ethoxide (1.7 g, 25 mmol), in absolute ethanol (50 mL). The reaction mixture was heated under reflux on a boiling water-bath for 4h, then cooled and poured onto ice-cold water. The solid so formed was filtered off and crystallized to give compounds **7a-7c**, respectively.

Method B

A solution of potassium hydroxide (1.12 g, 20 mmol) in ethanol (50 mL) was added to a mixture of sulfanylquinolinone **6** (1.91 g, 10 mmol) and ethyl iodide or butyl iodide (15 mmol). The mixture was heated under reflux on a boiling water-bath. The precipitate that formed was filtered off and crystallized to give compounds **7a** and **7b**, respectively (identified by m.p., mixed m.p. and spectral data).

4-Hydrazino-8-methylquinolin-2(1*H*)-one (**8**)

Method A

A mixture of chloroquinolinone **3** (1.94 g, 10 mmol) and hydrazine hydrate (5 mL, 0.1 mol), in absolute ethanol (30 mL), was heated under reflux for 4h. Then the mixture was left to cool and the crystals so obtained were filtered off and recrystallized.

Method B

A mixture of 4-ethylthioquinolinone **7a** (1.1 g, 5 mmol), hydrazine hydrate (2 mL, 40 mmol) and DMF (25 mL) was heated under reflux for 6h. The reaction mixture was left to cool, poured onto crushed ice to give white deposits, which were filtered off and crystallized.

Method C

Using the same above method *B*, compound **8** was obtained from 4-tosyloxyquinolone **9** (1.65 g, 5 mmol) and hydrazine hydrate (2 mL, 40 mmol) in DMF (25 mL).

8-Methyl-4-tosyloxyquinolin-2(1*H*)-one (**9**)

To a suspension of compound **1** (1.75 g, 10 mmol), in pyridine (50 mL), tosyl chloride (1.91 g, 10 mmol) was added portion-wise with continuous stirring. Then the mixture was heated under reflux on a boiling water-bath for 2h. The precipitate thus formed during the course of reaction was filtered off, washed thoroughly with acidified cold water, dried and crystallized.

4-Azido-8-methylquinolin-2(1*H*)-one (**10**)

Method A

To a solution of chloroquinolinone **3** (1.94 g, 10 mmol), in DMF (20 mL), sodium azide (1g, 15 mmol) was added and the mixture was heated under reflux for 2h. The reaction mixture was poured onto ice-cold water and the precipitate that formed was filtered off and crystallized.

Method B

Using the above method *A* compound **10** was also obtained from 4-tosyloxyquinolinone **9** (1.65 g, 5 mmol) and sodium azide (0.65, 10 mmol) in DMF (20 mL).

Method C

To a solution of hydrazinoquinolinone **8** (1.89 g, 10 mol), in 2 M hydrochloric acid (10 mL), sodium nitrite solution (10 mL, 11 mmol) was added drop-wise with continuous stirring, in a crushed

ice bath. The precipitate that formed was collected by filtration, washed and crystallized.

8-Methyl-4-(triphenylphosphoranylideneamino)quinolin-2(1*H*)-one (**11**)

A mixture of 4-azidoquinolone **10** (2.0 g, 10 mmol) and triphenylphosphine (2.88 g, 11 mmol), in benzene (50 mL) was heated under reflux on a boiling water-bath for 3h. Afterwards, the solvent was removed in vacuum and the residue was washed with diethyl ether (2 x 25 ml) and crystallized.

4-Amino-8-methylquinolin-2(1*H*)-one (**12**)

A suspension of phosphazene **11** (4.34 g, 10 mmol), in hydrochloric acid (50 mL) was heated under reflux for 4h. The solution was then left to cool and filtered from insoluble triphenylphosphine oxide. The acidic solution was neutralized using aqueous 2M sodium hydroxide solution (50 mL). The solid precipitates thus formed were filtered off and crystallized from DMF to give compound **12**, m.p.: > 300 °C (Lit. [1] m.p.: > 300 °C).

4-Chloro-2-methylthio-8-methylquinoline (**13a**)

To a solution of quinolinethione **4** (2.1 g, 10 mmol), in ethanolic potassium hydroxide (20 mL, 2 M), dimethyl sulfate (1.43 mL, 15 mmol) was added drop-wise with continuous stirring. Then the mixture was aerated over-night and the precipitate so formed was collected by filtration and crystallized.

4-Chloro-2-ethylthio-8-methylquinoline (**13b**)

A mixture of 4-chloroquinoline-2-thione **4** (2.1 g, 10 mmol) and ethyl iodide (1.21 mL, 15 mmol), in absolute ethanol (30 mL), was heated under reflux for 3h. Then, the mixture was left to cool and the precipitate that obtained was collected by filtration and crystallized.

2,4-Dihydrazino-8-methylquinoline (**14**)

A mixture of compound **13b** (2.38 g, 10 mmol) and hydrazine hydrate (2 mL, 40 mmol) was heated under reflux for 8h. Then the mixture was poured onto ice-cold water to give a precipitate, which was collected by filtration washed well with cold water and crystallized.

5-Azido-9-methyltetrazolo[1,5-*a*] quinoline (**15**)

To an icy solution of dihydrazinoquinoline **14** (1 g, 5 mmol) in hydrochloric acid (10 mL, 2 M), sodium nitrite solution (10 mL, 10 mmol) was added drop-wise over a period of 15 min in a crushed ice-bath. After stirring for additional 30 min, the reaction mixture was left at room temperature for a night. The precipitation so formed was collected by filtration and crystallized from THF to give

azidotetrazoloquinoline **15**, m.p.: 208-9 °C (Lit. [1] m.p.: 208 °C).

4-Alkyl(or phenyl)thio-8-methylquinoline-2(1*H*)-thiones **16a-c**

Compound **4** (2.1 g, 10 mmol) was dissolved in absolute ethanol containing sodium ethoxide (20 mmol) and treated with a proper thiol: ethanethiol, butanethiol, or thiophenol (20 mol) and the mixture was heated under reflux for 4h. Afterwards, the mixture was cooled, poured onto cold water and precipitated using hydrochloric acid (30 mL, 1 M). The solid so formed was filtered off and crystallized to give the sulfides **16a-c**, respectively.

4-Hydrazino-8-methylquinoline-2(1*H*)-thione (**17**)

Method A

To a solution of compound **4** (2.1 g, 10 mmol) in ethanol (30 mL) hydrazine hydrate (0.5 mL, 10 mmol) was added. The mixture was then heated under reflux for 4h, poured onto ice-cold water. The product so deposited was filtered off and crystallized.

Method B

To 10 mmol of either sulfides **16a** (2.35 g) or **16b** (2.63 g), hydrazine hydrate (1 mL, 2 mmol) was added and heated under reflux for 3h. On dilution of the cooled reaction mixture, a precipitate was obtained which was collected by filtration and crystallized.

4-Azido-8-methylquinoline-2(1*H*)-thione (**18**)

Method A

Using the same method A that used for obtaining compound **10**, chloroquinolinethione **4** (2.1 g, 10 mmol) was treated with sodium azide (0.65 g, 10 mmol) in boiling DMF (30 mL).

Method B

Using the same method B for obtaining compound **10**, compound **18** was obtained from hydrazinoquinolinethione **17** (2.05 g, 10 mmol) treated with hydrochloric acid (20 mL, 1 M) and sodium nitrite (10 mL, 10 mmol) at 0-5°C.

8-Methyl-4-(triphenylphosphoranylideneamino)quinoline-2(1*H*)-thione (**19**)

A similar procedure to that used for preparation of compound **11** was followed to obtain phosphazene **19** starting with azidoquinolinethione **18** (2.16 g, 10 mmol) and triphenylphosphine (2.62 g, 10 mmol) in dry benzene (50 mL).

4-Amino-8-methylquinolin-2(1*H*)-thione (20)

A similar method to that used for hydrolysis of compound **11** was followed. Compound **19** (4.5 g, 10 mmol) was suspended in 2 M hydrochloric acid (25 mL) and heated for 4h to give compound **20**.

Table 1. Analytical data of the new compounds.

Compd. No.	Yield (%)	M.P. (°C) Solvent	Mol. Formula Mol. Weight	Analyses (Calcd./Found)		
				C %	H %	N %
3	91	250-2 Dioxane	C ₁₀ H ₈ NCIO 193.5	62.02	4.13	7.24
				62.10	4.10	7.20
4	82 ^a , 10 ^b	154-5 EtOH	C ₁₀ H ₈ NCIS 209.5	57.28	3.80	6.68
				57.10	3.50	6.70
5	58 ^a , 8 ^b 45 ^c	246-8 EtOH	C ₁₀ H ₉ NS ₂ 207	57.97	4.35	6.76
				57.70	4.20	6.50
6	51	> 300 DMF	C ₁₀ H ₉ NOS 191	62.83	4.71	7.33
				62.50	4.70	7.00
7a	58 ^a , 79 ^b	216-7 AcOH	C ₁₂ H ₁₃ NOS 219	65.75	5.94	6.39
				65.60	5.80	6.10
7b	63 ^a , 56 ^b	212-3 EtOH	C ₁₄ H ₁₇ NOS 247	68.02	6.92	5.67
				67.90	6.60	5.60
7c	67 ^a	280-2 EtOH	C ₁₆ H ₁₃ NOS 267	71.91	4.87	5.24
				71.80	4.80	5.20
8	88 ^a , 75 ^b 53 ^c	> 300 DMF	C ₁₀ H ₁₁ N ₃ O 189	63.49	5.82	22.22
				63.60	5.80	22.30
9	70	222-224 MeOH	C ₁₇ H ₁₅ NSO ₄ 329	62.01	4.56	4.25
				62.00	4.50	4.20
10	60 ^a , 80 ^b 40 ^c	224 DMF	C ₁₀ H ₈ N ₄ O 200	60.00	4.00	28.00
				60.10	4.00	27.80
11	55	290 EtOH	C ₂₀ H ₂₃ N ₂ OP 434	77.42	5.29	6.45
				77.30	5.30	6.40
13a	65	75-7 MeOH	C ₁₁ H ₁₀ NCIS 223.5	59.06	4.47	6.26
				58.80	4.30	6.00
13b	78	144-6 EtOH	C ₁₂ H ₁₂ NCIS 237.5	60.63	5.05	5.89
				60.30	4.80	5.60
14	60	280-282 EtOH	C ₁₀ H ₁₃ N ₅ 203	59.11	6.40	34.48
				58.80	6.20	34.30
16a	66	187-8 Dioxane	C ₁₂ H ₁₃ NS ₂ 235	61.28	5.53	5.96
				61.00	5.50	5.80
16b	72	106-7 DMF	C ₁₄ H ₁₇ NS ₂ 263	63.88	6.46	5.32
				63.60	6.30	5.20
16c	85	223-5 AcOH	C ₁₆ H ₁₃ NS ₂ 283	67.84	4.59	4.95
				67.60	4.40	4.80
17	70 ^a , 74 ^b	> 300 EtOH	C ₁₀ H ₁₁ N ₃ S 205	58.54	5.37	20.49
				58.30	5.40	20.60
18	60 ^a , 75 ^b	172-4 DMF	C ₁₀ H ₈ N ₄ S 216	55.56	3.70	25.93
				55.40	3.60	25.70
19	70	208-10 CHCl ₃	C ₂₈ H ₂₃ N ₂ PS 450	74.67	5.11	6.22
				74.30	5.00	6.10
20	56	164-5 EtOH	C ₁₀ H ₁₀ N ₂ S 190	63.16	5.26	14.74
				63.10	5.10	14.50

^a, ^b and ^c yields by Methods A, B and C, respectively.

Table 2. IR and ¹H-NMR spectra of the new compounds.

Cpd.	IR, ν (cm ⁻¹)	¹ H-NMR, δ (ppm)
3	3190 (N-H), 1670 (C=O), 760 (C-Cl)	2.45 (s, 3H, CH ₃), 5.95 (s, 1H, C3-H), 7.10-7.90 (m, 3H, H _{arom}), 10.30 (bs, 1H, N-H)
4	3175 (N-H), 2600 (br S-H), 1275, 1205 (NHC=S), 762 (C-Cl)	1.95 (b, 0.4H, SH), 2.40 (s, 3H, CH ₃), 6.80 (s, 1H, C3-H), 6.95-7.80 (m, 3H, H _{arom}), 10.15 (b, 0.6H, N-H)
5	3245 (N-H), 2620-2550 (br S-H), 1290, 1145 (NHC=S)	1.65 (b, 0.4H, C2-SH), 1.90 (bs, 1H, C4-SH), 2.30 (s, 3H, CH ₃), 6.40 (s, 1H, C3-H), 7.05-8.15 (m, 3H, H _{arom}), 10.20 (b, 0.6H, N-H)
6	3165 (N-H), 2510 (br S-H), 1660 (C=O)	1.55 (bs, 1H, C4-SH), 2.35 (s, 3H, CH ₃), 6.60 (s, 1H, C3-H), 7.00-7.90 (m, 3H, H _{arom}), 10.45 (b, 1H, N-H)
7a	3170 (N-H), 1655 (C=O)	1.28 (t, 3H, SCH ₂ CH ₃), 2.40 (s, 3H, C8-CH ₃), 3.45 (q, 2H, SCH ₂ CH ₃), 6.80 (s, 1H, C3-H), 7.15-8.08 (s, 3H, H _{arom}), 10.45 (bs, 1H, N-H)
7b	3172 (N-H), 2965-2930 aliph C-H), 1660 (C=O)	1.25 (t, 3H, S(CH ₂) ₃ CH ₃), 1.35-1.45 (m, 4H, SCH ₂ (CH ₂) ₂ CH ₃), 2.45 (s, 3H, C8-CH ₃), 3.05 (t, 2H, SCH ₂ (CH ₂) ₂ CH ₃), 6.90 (s, 1H, C3-H), 7.15-8.05 (m, 3H, H _{arom}), 10.40 (bs, 1H, N-H)
7c	3140 (N-H), 1643 (C=O)	2.40 (s, 3H, CH ₃), 6.85 (s, 1H, C3-H), 7.10-8.05 (m, 8H, H _{arom}), 10.40 (bs, 1H, N-H)
8	3430, 3310-3278 (NH ₂), 3161 (N-H), 1645 (C=O)	2.35 (s, 3H, CH ₃), 4.30 (bs, 2H, NH ₂), 5.90 (s, 1H, C3-H), 7.10-7.90 (m, 3H, H _{arom}), 8.20 (bs, 1H, N-H _{hydrazino}), 10.30 (bs, 1H, N-H _{quinolone})
9	3172 (N-H), 3050 (arom C-H), 2956 (aliph C-H), 1648 (C=O), 1383, 1173 (S=O)	
10	3180 (N-H), 2120 (N ₃), 1660 (C=O)	2.55 (s, 3H, CH ₃), 6.80 (s, 1H, C3-H), 7.10-7.85 (m, 3H, H _{arom}), 10.55 (bs, 1H, NH)
11	3160 (N-H), 1645 (C=O), 1440 (P=N)	2.35 (s, 3H, CH ₃), 5.95 (s, 1H, C3-H), 7.10-8.00 (m, 18H, H _{arom}), 10.30 (bs, 1H, N-H)
13a	3066 (arom C-H), 2945-2901 (aliph C-H), 1610 (C=N), 762 (C-Cl), 660 (C-S)	2.60 (s, 3H, C8-CH ₃), 3.00 (s, 3H, S-CH ₃), 6.95 (s, 1H, C3-H), 7.25-8.05 (m, 3H, H _{arom})
13b	3065 (arom C-H), 2970 (aliph C-H), 1620 (C=N), 750 (C-Cl), 660 (C-S)	1.30 (t, 3H, SCH ₂ CH ₃), 2.65 (s, 3H, C8-CH ₃), 3.30 (q, 2H, SCH ₂ CH ₃), 7.05 (s, 1H, C3-H), 7.25-8.00 (m, 3H, H _{arom})
14	3450-3320 (NH ₂), 3190, 3180 (NH), 1610 (def. N-H, C=N)	
16a	3160 (N-H), 1605 (def. N-H), 1282, 1150 (C=S)	1.26 (t, 3H, SCH ₂ CH ₃), 2.40 (s, 3H, C8-CH ₃), 3.18 (q, 2H, SCH ₂ CH ₃), 6.75 (s, 1H, C3-H), 7.24-8.03 (m, 3H, H _{arom}), 10.20 (b, 1H, N-H)
16b	3140 (N-H), 2960-2900 (aliph C-H), 1612 (def N-H), 1270, 1143 (NHC=S), 695 (C-S)	1.28 (t, 3H, SCH ₂ (CH ₂) ₂ CH ₃), 1.35-1.50 (m, 4H, SCH ₂ (CH ₂) ₂ CH ₃), 2.15 (s, 3H, C8-CH ₃), 3.20 (t, 2H, SCH ₂ (CH ₂) ₂ CH ₃), 6.85 (s, 1H, C3-H), 7.15-8.05 (m, 3H, H _{arom}), 10.65 (bs, 1H, N-H)
16c	3200 (N-H), 3060 (arom C-H), 1605 (def N-H), 1280, 1147 (NHC=S), 670 (C-S)	2.40 (s, 3H, CH ₃), 6.80 (s, 1H, C3H), 7.20-8.03 (m, 8H, H _{arom}), 10.45 (s, 1H, N-H)
17	3430, 3365 (NH ₂), 3170 (N-H), 2600 (br S-H), 1620 (def N-H), 1250, 1145 (NHC=S)	1.95 (b, 0.3H, SH), 2.55 (s, 3H, CH ₃), 6.20 (bs, 2H, NH ₂), 6.45 (s, 1H, C3-H), 7.00-8.03 (m, 3H, H _{arom}), 8.15 (s, 1H, N-H _{hydrazino}), 10.20 (b, 0.7H, CSN-H)
18	3200 (N-H), 2120 (N ₃), 1600 (def N-H, str C=C), 1250, 1135 (NHC=S)	1.95 (s, 0.3H, S-H), 2.55 (s, 3H, CH ₃), 6.65 (s, 1H, C3-H), 7.05-8.15 (m, 3H, H _{arom}), 10.45 (bs, 0.7H, CSN-H)
19	3165 (N-H), 1610 (def N-H), 1425 (P=N), 1255, 1150, 1040 (NHC=S)	1.85 (s, 3H, CH ₃), 6.25 (s, 1H, C3-H), 6.95-8.05 (m, 18H, H _{arom}), 10.40 (s, 1H, N-H)
20	3430, 3320 (NH ₂), 3170 (N-H), 2520 (S-H), 1605 (def N-H, C=C), 1270, 1125 (NHC=S)	1.95 (s, 3H, CH ₃), 5.85 (s, 1H, C3-H), 6.40 (bs, 2H, NH ₂), 7.15-7.95 (m, 3H, H _{arom}), 10.40 (s, 1H, N-H)

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