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B. YOUSSEF

Textile Research Division, National Research Center, Dokki, Cairo, Egypt

M. AHMED

Organic Chem., Faculty of science, Benha University, Benha, Egypt.

H. MASHALY

Textile Research Division, National Research Center, Dokki, Cairo, Egypt

S. MAHMOUD

Textile Research Division, National Research Center, Dokki, Cairo, Egypt

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SYNTHESIS OF SOME ANTIBACTERIAL FUNCTIONAL CATIONIC DYES

B.M.YOUSSEF¹, M.H.M.AHMED², H.M.MASHALY¹ and S.A.MAHMOUD¹.

¹*Textile Research Division, National Research Center, Dokki, Cairo, Egypt*

²*Organic Chem., Faculty of science, Benha University*

Abstract

In this study, the idea is to combine the traditional dyes and functional finishing together through suitable chemical linkages, thus the whole structure may be regarded as a functional dye. Novel some new antibacterial cationic dyes were synthesized by reacting N, N-Dimethyl (heptyl, decyl and hexadecyl) amine with anthraquinone derivatives, respectively. The structures of the synthesized dyes were fully elucidated by using FTIR, ¹H-NMR, ¹³C-NMR and elemental analysis. All synthesized cationic dyes showed antibacterial activities. This will be discussed later in another paper.

Keywords: Synthesis; characterization; Antibacterial; Quaternary ammonium salts; cationic dyes;

Introduction

The most important process of wetting treatment for textile materials are dyeing and finishing processes [1-8]. The combination of dyeing and finishing into one step or one bath is obviously an approach. If a functional agent was chemically incorporated into dye without significantly affecting its dyeing properties, the textile dyeing and finishing processes could be unified into one process [9-10].

The functional finishing dyes allow dyeing and functional finishing to be achieved simultaneously thereby reducing the amount of solvent used and the amount of waste solvent generated. Also, reduction of labor and time required to produce such treated textile [11-12].

Functional dyes with special finishing capabilities currently are an area of active research [13]. Many functional dyes, such as water-repellent dyes [14-15], anti-UV-radiation dyes [16-18] and antimicrobial azodyes [19] have been reported. Anthraquinone dyes are the second most important class of dyes [20-23].

The present study is an attempt to synthesis a some new antibacterial cationic dyes by incorporating biocidal quaternary ammonium salts (QAS) into amino anthraquinoid dye via chemical linkage. QAS inactivate and kill microorganisms [24]. Meanwhile, anthraquinones play an important role as dyes, for their molecular

stability and outstanding light fastness. Attention is focused to synthesis two novel series of cationic dyes based on anthraquinone. The antibacterial activity of synthesized dyes was evaluated against Gram-positive and Gram-negative bacteria; this will be published in part tow of this work.

Experimental:

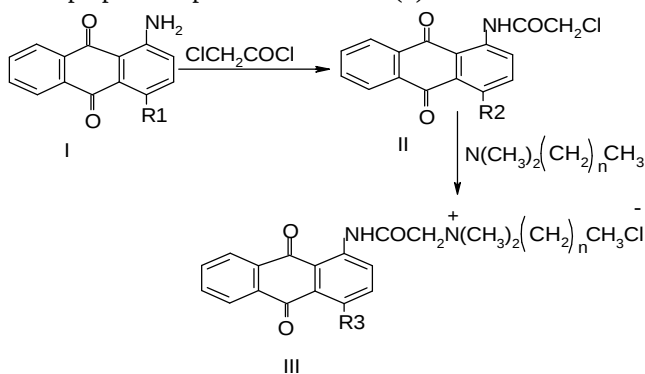
All melting points were determined by an electro thermal digital melting point apparatus and are uncorrected. IR spectra were recorded in KBr disks using a PYA UNICAM spectra 1000 FT-IR spectrophotometer. ^1H NMR (400MHz) and ^{13}C NMR (100MHz) spectra were recorded on a VARIAN 400MHz spectrometer in CDCl_3 or DMSO as solvent and TMS (siMe4) as internal standard; chemical shifts are reported in δ units (ppm). UV spectra were recorded on a Perkin Elmer Lamb 15 UV/Vis spectrophotometer.

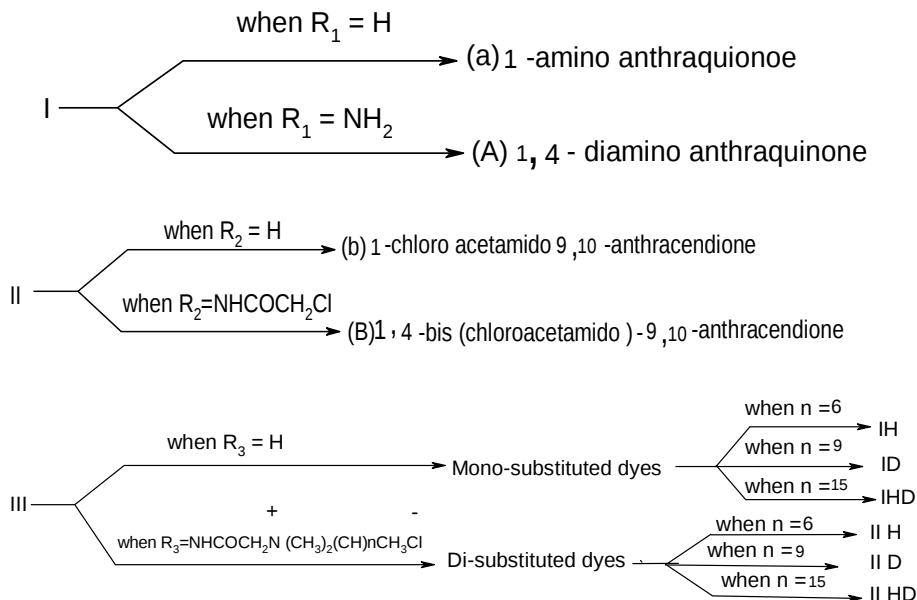
Materials:

1,4-Diaminoanthraquinone (90%, Aldrich) was purified by repeated crystallization from acetone. 1-Aminoanthraquinone (97%, Aldrich), chloroacetyl chloride (99%, Fluka), N, N-dimethylheptylamine (97%, Fluka), N,N-dimethyldecylamine (90%, Aldrich), N,N- dimethylhexadecyllamine (95%, Fluka) , were used as received.

Synthesis: [25]

Over all the reaction was completed according to the following scheme 1. The list of compounds prepared is presented in Table (1).





Scheme1. Synthetic procedures for cationic dyes (n = 6, 9, 15)

Synthesis of IH:

Typical procedure of the reaction steps; is outlined as follows:

(I) Acetylation reaction:

(0.01 mol, 2.23 gm) 1-aminoanthraquinone (a) in 30 ml dimethylacetamide as solvent was cooled to $0^\circ C$, and 5 ml (0.06 mol, 6.78gm) chloroacetyl chloride in 150 ml of chloroform was slowly added to the reaction mixture with vigorous stirring. The reaction mixture was further stirred for one hour at room temperature to complete the reaction; the solvent was evaporated under vacuum. The product was precipitated by addition of ethyl ether. The crude product (b) (1-chloroacetamido-9,10-anthracenedione) was taken to next step with purification. Yield percentage 94.5%.

(II) Nucleophilic substitution reaction (Quaternization):-

A suspension solution of (b) prepared from the previous step (0.01mol, 2.995 gm) in 200 ml DMF, mixed with (0.1 mol, 14.3 gm) N, N-dimethylheptylamine, were

heated under reflux at 95°C for 3 hours. The solvent (DMF) was removed under reduced pressure; the product was purified from ethyl ether. Yield percentage 42.85 %, melting point: 184 - 186°C. IR spectra data (KBr): $\nu_{C=O}$ of -NH-CO- at 1668.79 cm^{-1} . $^1\text{H-NMR}$ spectra data (DMSO, δ ppm) at 12.159 (singlet, 1H, -NH-CO); 8.657~7.892 (doublet, multiplet, 7H, of anthaquinone protons); 4.762 (singlet, 2H, -CO-CH₂-N⁺(CH₃)₂-(CH₂)₆CH₃Cl⁻); 3.646 (multiplet, 2H, -N⁺(CH₃)₂CH₂-(CH₂)₅CH₃Cl⁻); 3.373 (singlet, 6H, -N⁺(CH₃)₂-(CH₂)₆-CH₃Cl⁻); 1.822 (multiplet, 2H, -N⁺(CH₃)₂-CH₂-CH₂(CH₂)₄CH₃Cl⁻); 1.279 (multiplet, 8H, -N⁺(CH₃)₂-CH₂-CH₂-(CH₂)₄-CH₃Cl⁻); 0.844 (triplet, 3H, -N⁺(CH₃)₂-(CH₂)₅-CH₂-CH₃Cl⁻).

Synthesis of ID:

It was prepared by using the same procedure stated before. The yield percentage 60.5 %, melting point: 176 °C. IR spectra data (KBr): $\nu_{C=O}$ of -NH-CO- at 1673.4 cm^{-1} , $^1\text{H-NMR}$ spectra data (CDCl₃, δ ppm) at 12.438 (singlet, 1H, -NH-CO); 8.978 ~ 7.265 (doublet, multiplet, 7H, of anthaquinone protons); 5.36 (singlet, 2H, -CO-CH₂-N⁺(CH₃)₂-(CH₂)₉CH₃Cl⁻); 3.878 (multiplet, 2H, -N⁺(CH₃)₂CH₂-(CH₂)₈CH₃Cl⁻); 3.699 (singlet, 6H, -N⁺(CH₃)₂-CH₂-(CH₂)₈CH₃Cl⁻); 1.827 (multiplet, 2H, -N⁺(CH₃)₂-CH₂-CH₂-(CH₂)₇CH₃Cl⁻); 1.276~1.197 (multiplet, 14H, -N⁺(CH₃)₂-CH₂-CH₂-(CH₂)₇-CH₃Cl⁻); 0.844~0.824 (triplet, 3H, -N⁺(CH₃)₂-(CH₂)₈-CH₂CH₃Cl⁻).

Synthesis of IHD:

By following similar procedures to that stated before, IHD was also prepared. Yield percentage was 51.22 % and the melting point 188 °C. IR spectra data (KBr): $\nu_{C=O}$ of -NH-CO at 1625.7 cm^{-1} . $^1\text{H-NMR}$ spectra data (CDCl₃, δ ppm) at 12.552 (singlet, 1H, -NH-CO-); 8.608 ~ 7.258 (doublet, multiplet, 7H, of anthaquinone protons); 4.5 (singlet, 2H, -CO-CH₂-N⁺(CH₃)₂(CH₂)₁₅CH₃Cl⁻); 3.986 ~ 3.950 (multiplet 2H, -N⁺(CH₃)₂-CH₂-(CH₂)₁₄CH₃Cl⁻); 3.773 (singlet, 6H, -N⁺(CH₃)₂-CH₂-(CH₂)₁₄CH₃Cl⁻); 1.853 (multiplet, 2H, -N⁺(CH₃)₂-CH₂-CH₂-(CH₂)₁₃CH₃Cl⁻); 1.332, 1.218 (multiplet, 28 H, -N⁺(CH₃)₂-CH₂-CH₂-(CH₂)₁₄-CH₃Cl⁻); 0.861 ~ 0.803 (triplet, 3H, -N⁺(CH₃)₂-(CH₂)₁₄-CH₂-CH₃Cl⁻).

Synthesis of II H

(I) Acetylation reaction:

(0.01 mol, 2.38gm) 1,4-diaminoanthraquinone (A) in 30 ml dimethylacetamide at 0 °C was reacted with 9.56 ml (0.12 mol, 13.56gm) chloroacetyl chloride in 300 ml chloroform was slowly added with vigorous stirring. The reaction mixture was further stirred for one hour at room temperature; the solvent was evaporated under vacuum. The product was precipitated by addition of ethyl ether. The crude product 1, 4-bis(chloroacetamido)- 9,10-anthracendione (B) was purified by recrystallization from DMF, yield of 93.9%.

(II) Nucleophilic substitution reaction (Quateranization):

A suspension solution of (0.01 mol, 3.91gm) 1,4-bis(chloroacetamido)-9,10-anthracenedione (B) in 300 ml DMF, together with (0.2mol, 28.6gm) N,N-dimethylheptylamine, was heated under reflux at 95 °C for 3 hours. The final product was also purified by ethyl ether, yield percentage 52.88%, melting point: 255 °C. IR spectra data (KBr): ν C=O of -NH-CO at 1687.32 cm^{-1} ; ν N-H at 3422.5 cm^{-1} as broad band. ^1H NMR spectra data (CDCl_3 , δ ppm) at 12.2(singlet, 2H, -NH-CO); 8.548~7.99 (multiplet, 6H, of anthraquinone protons); 4.728(singlet, 4H, [-CO-CH₂-N⁺(CH₃)₂-(CH₂)₆CH₃ Cl⁻]₂); 3.629 ~ 3.593 (multiplet, 4H, [-N⁺(CH₃)₂-CH₂-(CH₂)₅CH₃ Cl⁻]₂); 3.362(singlet, 12H, [-N⁺(CH₃)₂-CH₂-(CH₂)₅CH₃ Cl⁻]₂); 1.815 (multiplet, 4H, [-N⁺(CH₃)₂-CH₂-CH₂-(CH₂)₄CH₃ Cl⁻]₂); 1.3(broad peak, 16H, [-N⁺(CH₃)₂-CH₂-CH₂-(CH₂)₄-CH₃ Cl⁻]₂); 0.861~0.83 (triplet, 6H, [-N⁺(CH₃)₂-(CH₂)₅-CH₂-CH₃ Cl⁻]₂).

Synthesis of II D:

It was prepared by using the procedure described for the preparation of IIIH. Yield: 65%, melting point: 235 °C. IR spectra data (KBr): ν C=O of -NH-CO- =1686.7 cm^{-1} ; ν N-H at 3394.8 cm^{-1} as broad band. ^1H -NMR spectra data (CDCl_3 , δ ppm) at 12.411(singlet, 2H, [-NH-CO]₂); 7.907~7.263 (multiplet, 6H, of anthaquinone protons) 5.914(singlet, 4H, [-CO-CH₂-N⁺(CH₃)₂-(CH₂)₉CH₃ Cl⁻]₂); 4.031(multiplet, 4H, [-N⁺(CH₃)₂-CH₂-(CH₂)₈CH₃ Cl⁻]₂); 3.77(singlet, 12H, [-N⁺(CH₃)₂-CH₂-(CH₂)₈CH₃]₂); 1.879(multiplet, 4H, [-N⁺(CH₃)₂-CH₂-CH₂-(CH₂)₇CH₃ Cl⁻]₂); 1.241, 1.377(multiplet, 28H, [-N⁺(CH₃)₂-CH₂-CH₂-(CH₂)₇-CH₃ Cl⁻]₂); 0.882 ~ 0.821 (triplet, 6H, [-N⁺(CH₃)₂-(CH₂)₈-CH₂-CH₃ Cl⁻]₂).

Synthesis of II HD:

IIHD was prepared in the similar procedure as preparing IIH. Yield: 40.3%, melting point: 256~259 °C. IR spectra data (KBr): -NH-CO at 1687.18 cm^{-1} ; ν N-H at 3417.4 cm^{-1} as broad band. ^1H NMR spectra data (CDCl_3 , δ ppm) at 12.377 (singlet, 2H, $-\text{[NH-CO]}_2$), 7.849 ~ 7.266 (multiplet, 6H, of anthraquinone protons); 5.891 (singlet, 4H, $-\text{CO-CH}_2\text{-N}^+(\text{CH}_3)_2\text{-(CH}_2\text{)}_{15}\text{CH}_3\text{Cl}^-]_2$); 4.012 (multiplet, 4H, $-\text{N}^+(\text{CH}_3)_2\text{-CH}_2\text{-(CH}_2\text{)}_{14}\text{CH}_3\text{Cl}^-]_2$); 3.759 (singlet, 12H, $-\text{N}^+(\text{CH}_3)_2\text{-CH}_2\text{-(CH}_2\text{)}_{14}\text{CH}_3\text{Cl}^-]_2$); 1.868 (multiplet, 4H, $-\text{N}^+(\text{CH}_3)_2\text{-CH}_2\text{-CH}_2\text{-(CH}_2\text{)}_{13}\text{CH}_3\text{Cl}^-]_2$); 1.367, 1.244, 1.114 (multiplet, 56H, $-\text{N}^+(\text{CH}_3)_2\text{-CH}_2\text{-CH}_2\text{-(CH}_2\text{)}_{14}\text{-CH}_3\text{Cl}^-]_2$); 0.858 ~ 0.847 (triplet, 6H, $[\text{N}^+(\text{CH}_3)_2\text{-(CH}_2\text{)}_{14}\text{-CH}_2\text{-CH}_3\text{Cl}^-]_2$).

Results and discussion

Synthesis:

All (antibacterial) cationic dyes (IH-IHD; IIH-IIHD) were synthesized by reaction of anthraquinone derivatives (a, A) with chloroacetylchloride to give intermediate (b) and (B) with good yields. The resultant intermediate was reacted with N, N- dimethyl (heptyl, decyl, hexadecyl) amine in DMF as a solvent to give the final products with yield percentage ranging from 40 to 65 %. The purification of the prepared dyes proceeds using ethyl ether as washing solvent. The synthetic procedures are outlined in scheme 1.

Proposed Dyes structure

The chemical structures of 1-chloroacetamido -9,10-anthracenedione(b), 1,4-bis(chloroacetamido)-9,10-anthracenedione(B) intermediates and synthesized antibacterial cationic dyes (1-6) are shown in figure (1) and in Table (1) .

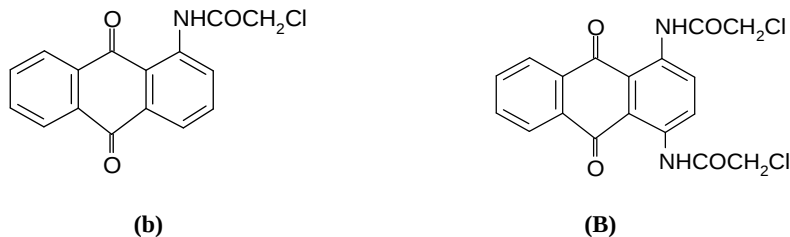
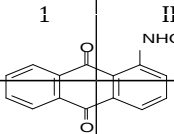
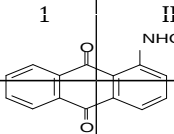
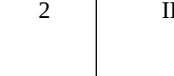
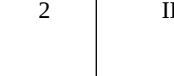
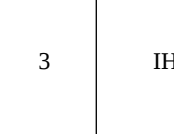
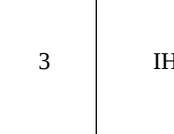
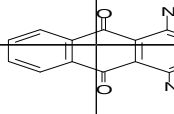
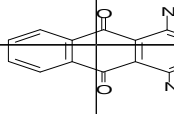
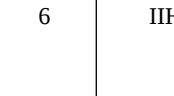
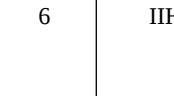


Figure (1)

Table (1): The synthesized dyes:

Dye No	compounds	Dye structure	λ_{max}
1	IH  $\text{NHCOCH}_2\text{N}(\text{CH}_3)_2(\text{CH}_2)_6\text{CH}_3\text{Cl}^-$		357
2	ID 		364
3	IHD 		390
4	IIH		429
5	IID  $\text{NHCOCH}_2\text{N}(\text{CH}_3)_2(\text{CH}_2)_9\text{CH}_3\text{Cl}^-$		433
6	IIHD 		450

Elucidation of present synthesized cationic dyes structure:

IR analysis

The IR spectra of the prepared antibacterial cationic dyes (1-6 as pointed in Table 1.) are shown in Fig (2,3) These antibacterial cationic dyes showed a characteristic absorption band of the carbonyl groups (C=O) of the amide structures at the range $1600\sim 1680\text{cm}^{-1}$. Absorption band at the range $1700\sim 1710\text{cm}^{-1}$ which can be attributed to the C=O stretching bond of the anthraquinone structures. The IR spectra of synthesized dyes also showed absorption band at the range $3390\sim 3423\text{cm}^{-1}$

corresponding to NH group of the amid structures. CH aromatic appear in all synthesized dyes at the rang 3010 -3017 cm^{-1} .CH aliphatic bands at the range 2800-3000 cm^{-1} . It is also interesting to note that with the increased of alkane chain length in quaternary ammonium salts, the intensity of the alkane absorption bands (2800-3000 cm^{-1}) also gradually increased.

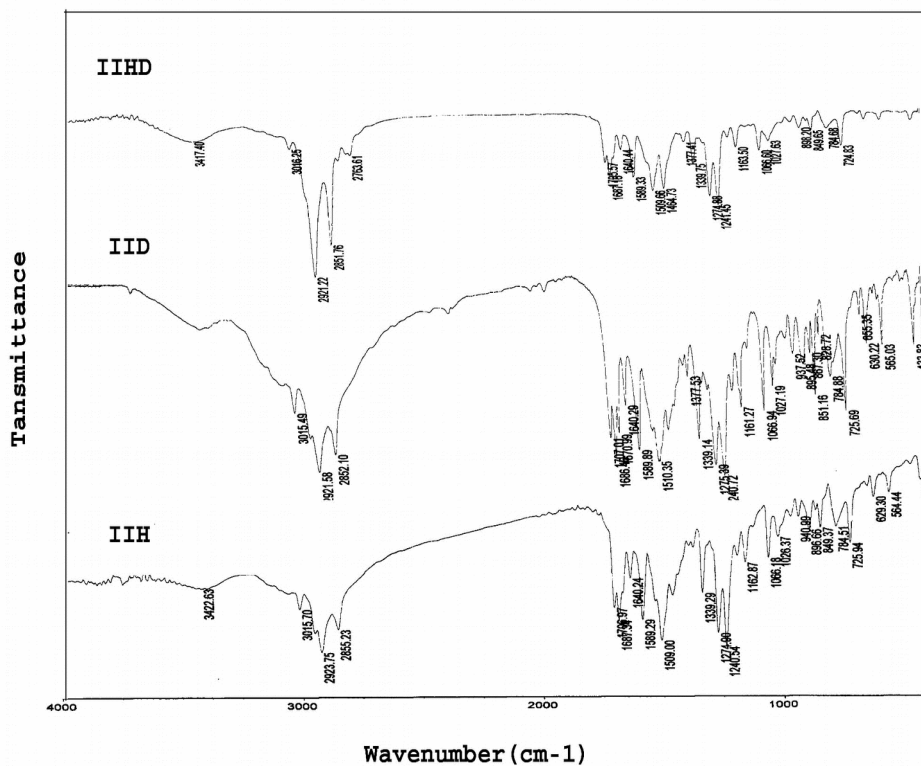


Fig. (2) IR of spectra of di - substituted dyes

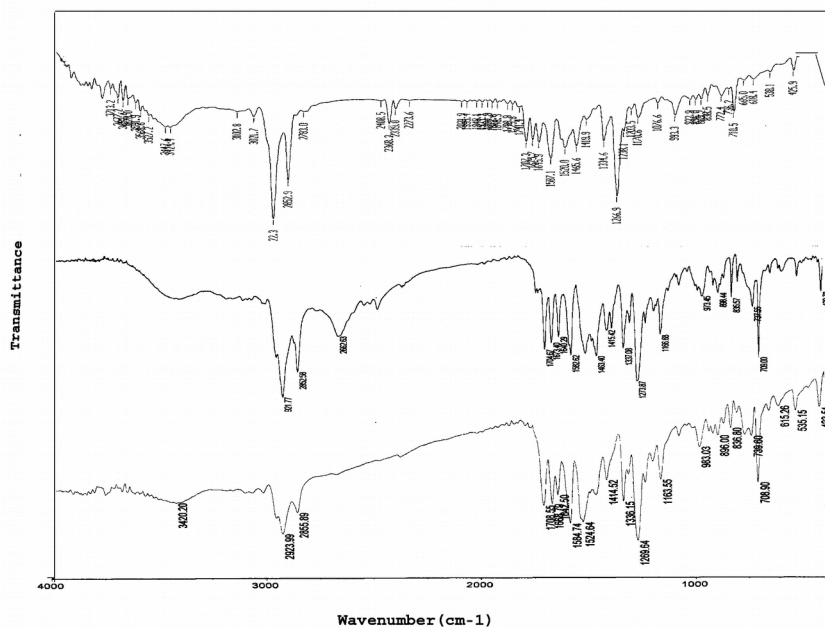


Fig. (3) IR of spectra of mono – substituted dyes

¹H-NMR analysis:

The chemical structures of the synthesized dyes are further confirmed by ¹H-NMR Analysis. The corresponding spectra of these compounds are shown Figs. (4 - 8) . As an example, Fig. (4) shows the ¹H-NMR spectrum of compound IH . The peaks in the range of δ 7.892 ~8.657 ppm are due to the aromatic protons. Also, several characteristic peaks of the dyes can also be found, for example, the peak appears at 12.159 ppm is resulted from the amid proton, the signal at 4.762 ppm is attributed to CH₂ protons of NH- CO-CH₂-N⁺ (CH₃)₂- (CH₂)₆-CH₃Cl (see Fig 4).

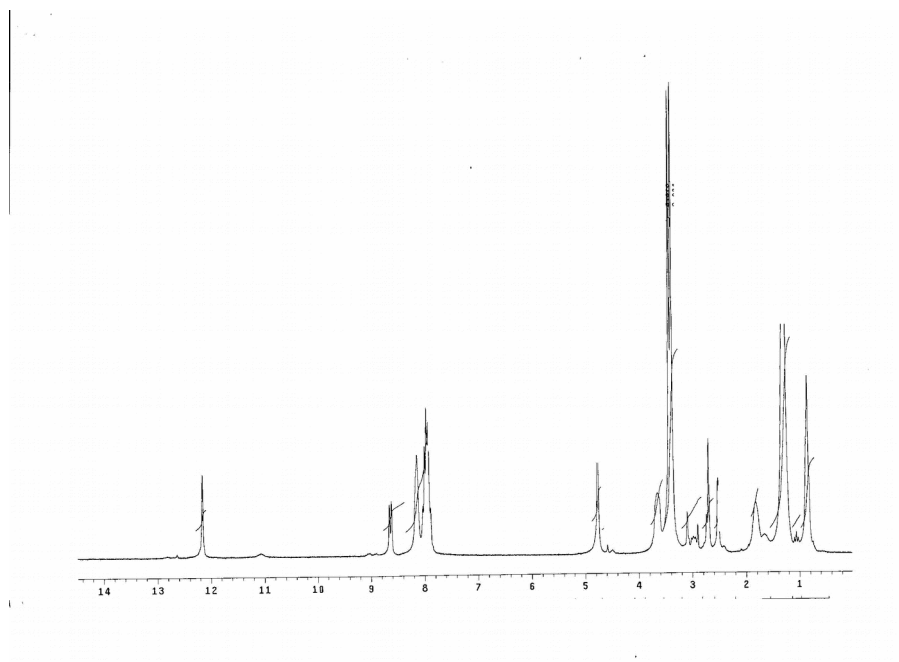
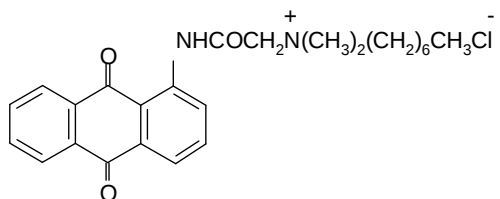


Fig. (4) $^1\text{H-NMR}$ of spectra of 1H

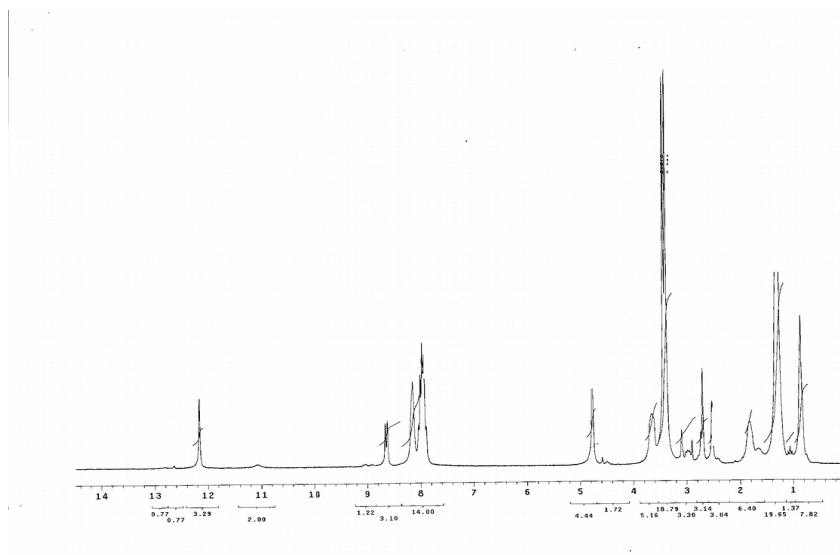
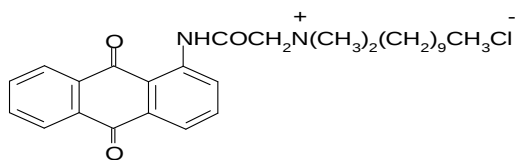


Fig. (5) $^1\text{H-NMR}$ of Spectra of ID

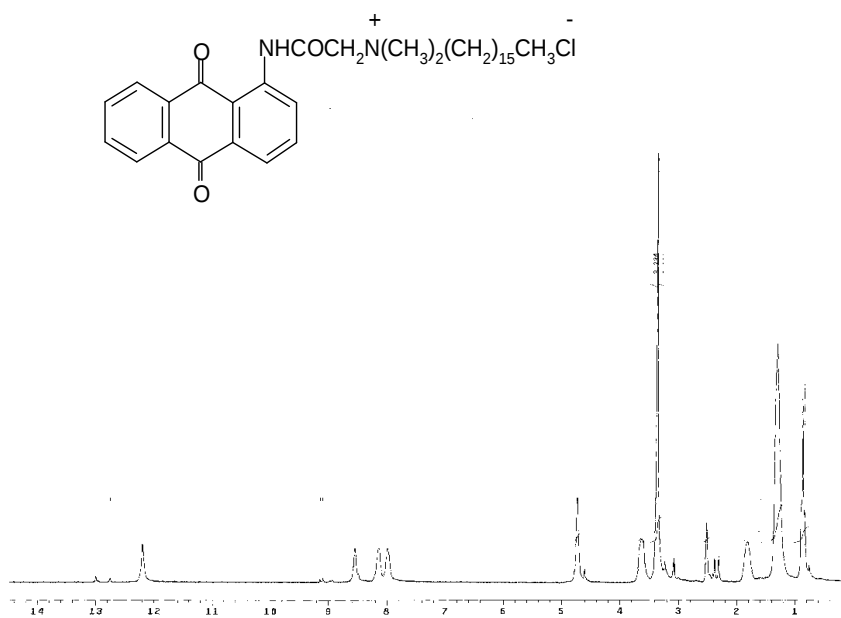


Fig. (6) $^1\text{H-NMR}$ of Spectra of IIIH

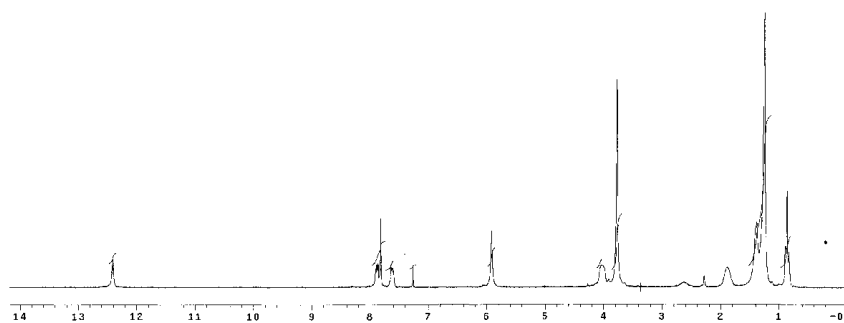
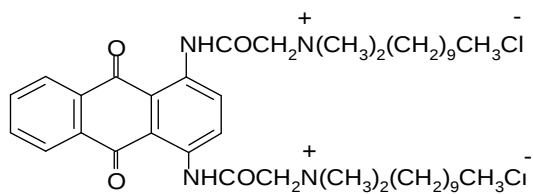


Fig. (7) $^1\text{H-NMR}$ of Spectra of IID

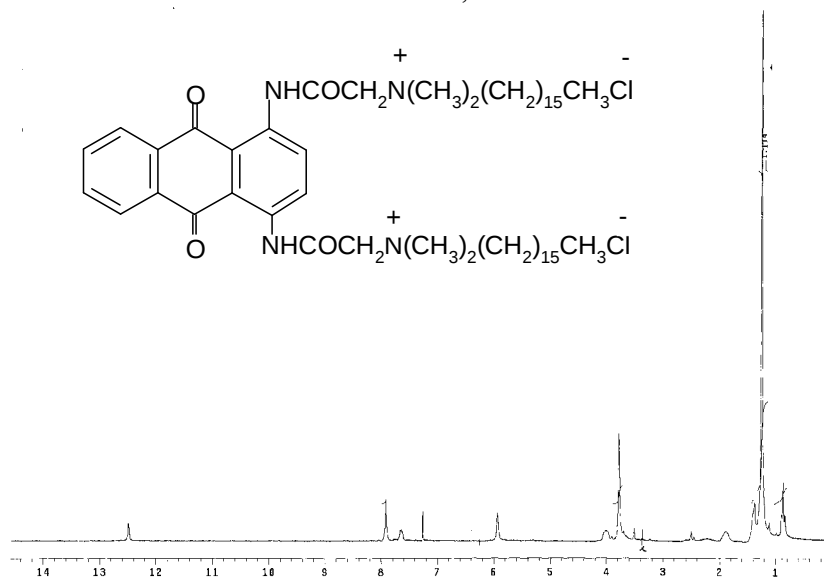


Fig. (8) $^1\text{H-NMR}$ of Spectra of IIHD

$^{13}\text{C-NMR}$ analysis:

$^{13}\text{C-NMR}$ analysis is also conducted to confirm the chemical structures of the synthesized dyes. The spectra are shown in Figs.(9 - 12). As shown in Fig. (9) the $^{13}\text{C-NMR}$ spectrum of IH give the peaks at 185.8274 and 181.9739 ppm are assigned to the two carbonyl carbons in the anthraquinone structure, respectively, the peak at 163.241 ppm is assigned to the amid carbon, the peaks in the range of 121.6249 ~ 135.5032 ppm are caused by aromatic carbons, and the peaks within 10 ~ 70 ppm are corresponding to the ten alkyl carbons chain, $[-\text{N}^+(\text{CH}_3)_2-\text{CH}_2-\text{CH}_2-(\text{CH}_2)_4-\text{CH}_3 \text{ Cl}^-]$ which locate in different chemical environments. However, Fig.(11) shows the $^{13}\text{C-NMR}$ spectrum of IIH, the peak at 185.4745 ppm is assigned to the carbonyl carbons in the anthraquinone structure, the peak at 163.25502 ppm is assigned to the amid carbon, the peaks in the range of 121.5296 ~ 135.1884 ppm are due to aromatic carbons, and the peaks within 10 ~ 70 ppm are corresponding to the alkyl carbons, $[-\text{N}^+(\text{CH}_3)_2-\text{CH}_2-\text{CH}_2-(\text{CH}_2)_4-\text{CH}_3 \text{ Cl}^-]_2$; Exactly the appearance of mono and di-substituted cationic dyes are at the same signal position, the difference was relevance by the appearance of two ^{13}C NMR signals of the two different

environment carbonyl groups of mono-substituted dyes while in case of disubstituted cationic dyes only one type of signals appear at 185.4745 of these two carbonyl groups. All these data pointed that new suggested cationic dyes can be readily synthesized following Scheme 1.

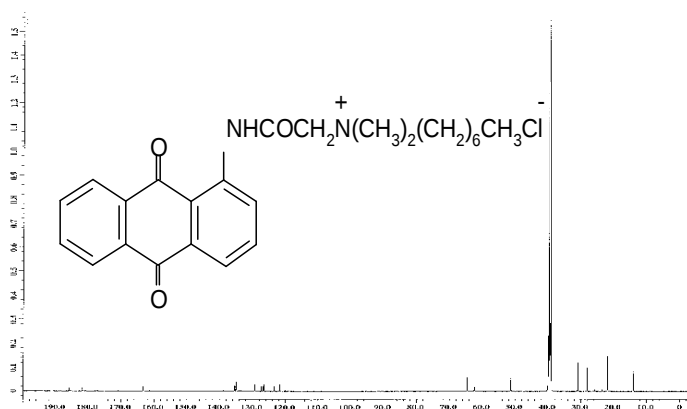


Fig . (9) ^{13}C -NMR spectra of IH

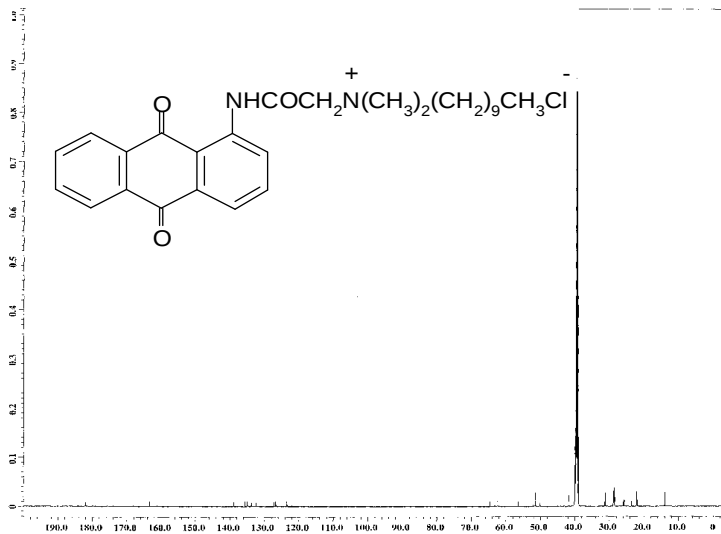
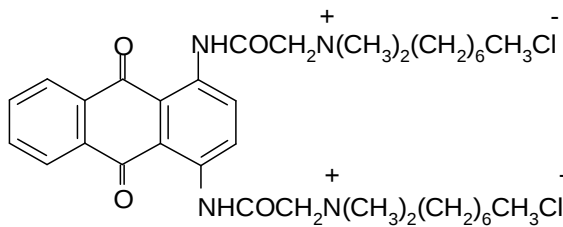
**Fig. (10)** ^{13}C -NMR OF spectra of 1D

Fig. (11) ^{13}C -NMR OF spectra of IIIH

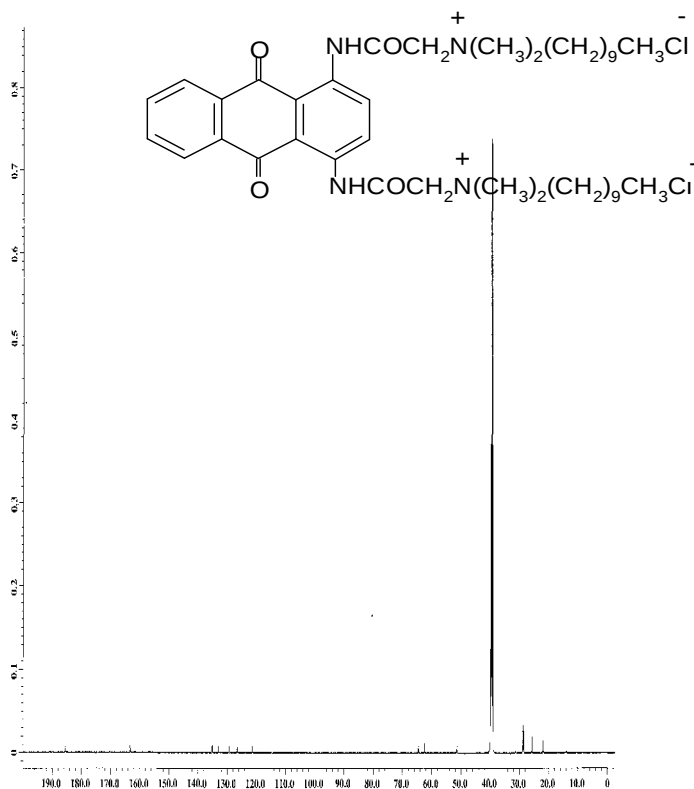


Fig. (12) ^{13}C -NMR of spectra of IID

Conclusion:

Two series of novel antibacterial cationic dyes were prepared by incorporating QAS into 1-chloroacetamido -9,10-anthracenedione and / or 1,4-bis(chloroacetamido)-9,10-anthracenedione with yield percentage ranging from 40 to 65 %. It was found that all the di-substituted dyes showed a greater bathochromicity compared to the mono - substituted. The structures of the synthesized dyes were elucidated by using FI - IR, ^1H -NMR and ^{13}C - NMR.

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