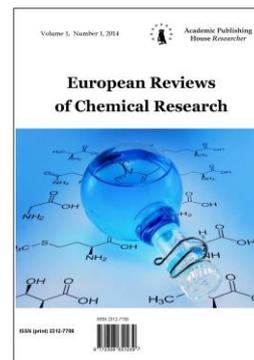


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Synthesis of Different Classes of Polyheterocyclic Cyanine Dyes: a Review

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Abstract

In this review paper some synthesis of different classes of polyheterocyclic cyanine dyes have been reviewed. In this paper review detailed synthesis steps for the synthesis of some polyheterocyclic cyanine dyes were represented via equations. This is covers the synthesis of polyheterocyclic monomethine cyanine dyes (simple cyanine dyes), dimethine cyanine dyes, trimethine cyanine dyes (carbocyanine dyes), pentamethine cyanine dyes (dicarbocyanine dyes), styryl cyanine dyes (hemicyanine dyes), aza-styryl cyanine dyes (aza-hemicyanine dyes) and apocyanine dyes. Besides, in the introduction section of this review paper some light is focused on some important uses, applications, characterizations and properties of cyanine dyes. This review paper is very readable, informative, and useful for synthetic dye chemists, researchers and students who look for the different methods in the synthesis and preparation of various classes of polyheterocyclic cyanine dyes. In addition, this paper review can be used and/or will be most valuable as a thesis and/or as a note book for student lectures, particularly for the post graduate students and researchers in the field of heterocyclic and/or cyanine dyes chemistry. This special and/or specific type of collective review in the synthesis of different classes of only polyheterocyclic cyanine dyes has been paid no attention and is absence in the chemistry literature.

Keywords: cyanine dyes, synthesis, polyheterocyclic cyanine dyes, different classes of cyanine dyes, uses of cyanine dyes, applications of cyanine dyes, properties of cyanine dyes.

1. Introduction

The first cyanine dye was discovered in 1856 by C.H. Greville Williams. Later in 1873, H.W. Vogel began to use cyanine dyes in photography (Hamer, 1964). Since then, research on cyanine dyes developed (Chen, 2006) rapidly due to their extra sensitizing power on silver halide in the region of spectra from visible to near infrared (IR) in photography.

Cyanine dyes (Shindy, 2014; Shindy, 2015; Shindy 2015a; Shindy 2012) have relatively good stability, high molar absorption coefficients, medium fluorescence intensity, narrow spectrum width and the ability to form H- or J-aggregates. The maximum absorption wavelength of cyanine dyes can be tuned precisely from near-UV to near-IR by chemical structure modification. With these unique photophysical and photochemical properties, cyanine dyes are recently being used in many applications such as nonlinear optics, optical data storage, bimolecular labeling, dye laser, photorefractive materials and photodynamic therapy (Mishra et al., 2000).

In recent years, there has been increased interest in the field of the synthesis and application of cyanine dyes absorbing in different visible spectral regions, suitable as nucleic acid labels.

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The number of both patents (Roth et al., 1995; Yue et al., 1996; Yue et al., 1994; Yue et al., 1997; Lee, 1997) and scientific publications (Deligeorgiev et al., 1995; Deligeorgiev et al., 1998; Yarmoluk, et al., 1996; Moreda et al., 1997) is an strong evidence for the commercial (Haugland, 1996), scientific (Timcheva et al., 1997; Zeng et al., 1997; Josef et al., 1996; Millard et al., 1997; Roth et al., 1997; Gurrieri et al., 1997; Clark et al., 1997) and practical importance of these probes in nucleic acid research, clinical and environmental analysis.

Additional important and interesting properties, characterizations and applications of cyanine dyes ((Shindy, 2016; Shindy, 2017; Shindy, 2018; Shindy, 2018a; Shindy et al., 2018) also covers and/or includes the following:

1-Cyanine dyes are photosensitizers dyes, and this can be evaluated through examining their electronic visible absorption spectra in 95 % ethanol solution. The cyanine dyes were thought to be better photosensitizers when they absorb the visible light to initiate the electronic transitions at higher wavelength bands (bathochromic shifted and/or red shifted dyes). Consequently, the photosensitization of the cyanine dyes decreases when they absorb the visible light to initiate the electronic transitions at lower wavelength bands (hypsochromic shifted and/or blue shifted dyes). So, we may say that the photosensitization of one cyanine dye is higher than the other one if the wavelength of the maximum absorption spectrum of the former one is longer than that of the latter one. In contrary, we may say that the photosensitization of one cyanine dye is lower than the other one if the wavelength of the maximum absorption spectrum of the former one is shorter than that of the latter one. Studying the electronic visible spectra of cyanine dyes in 95 % ethanol solution is very important in the case of cyanine dyes because the extensive uses of these dyes as photographic sensitizers for silver halide emulsion in photosensitive material industry for colored and non colored (black and white) films (cyanine dyes were originally used, and still are, to increase the sensitivity range of photographic emulsions, i. e. to increase the range of wavelengths which will form an image on the film).

2-Cyanine dyes are solvatochromic dyes, and this can be evaluated through measuring their electronic visible absorption spectra in pure solvent having different polarities The cyanine dyes were thought to be better solvatochromic properties when they give strong positive and/or negative solvatochromism in pure solvents having different polarities. Consequently, the solvatochromic properties of the cyanine dyes decrease when they give weak positive and/or negative solvatochromism in pure solvent having different polarities. So, we may say that the solvatochromic properties of one cyanine dye is higher than the other one if the positive and/or the negative solvatochromism in pure solvents having different polarities of the former one is stronger than that of the latter one. In contrary we may say that the solvatochromic properties of one cyanine dye is lower than the other one if the positive and/or the negative solvtochromism in pure solvnt having different polarities of the former one is weaker than that of the latter one. Positive solvatochromism reveals bathochromic shifted (red shifted) absorption bands with increasing solvent polarity. In contrast, negative solvatochromism discloses hypsochromic shifted (blue shifted) bands with increasing solvent polarity. Solvatochromic evaluation study is very important in the case of cyanine dyes because the extensive uses and application of these dyes in textile industry and/or as probes for determining solvent polarity in physical, physical organic, inorganic and/or solution chemistry.

3-Cyanine dyes are halochromic dyes, and this can be evaluated through examining their electronic visible absorption spectra in aqueous universal buffer solutions owing varied pH values. The cyanine dyes were thought to be better halochromic properties when they give strong positive and/or negative halochromism in aqueous universal buffer solutions having varied pH values. Consequently, the halochromic properties of the cyanine dyes decrease when they give weak positive and/or negative halochromism in aqueous universal buffer solutions having varied pH values. So, we may say that the halochromic properties of one cyanine dye is higher than the other one if the positive and/or the negative halochromism of the former one in aqueous universal buffer solutions having varied pH values is stronger than that of the latter one. In contrary we may say that the halochromic properties of one cyanine dye is lower than the other one if the positive and/or the negative halochromism of the former one in aqueous universal buffer solutions having varied pH values is weaker than that of the latter one. Positive halochromism means occurrence of a bathochromic shifted (red shifted) absorption bands with changing solution pH of the buffer solution. In contrast, negative halochromism means occurrence of a hypsochromic shifted (blue

shifted) absorption bands with changing the pH of the buffer solution. Halochromic evaluation study in aqueous universal buffer solutions having varied pH values have a great practical importance in the case of cyanine dyes because the wide uses and applications of these dyes as indicators in operations of acid / base titrations in analytical chemistry.

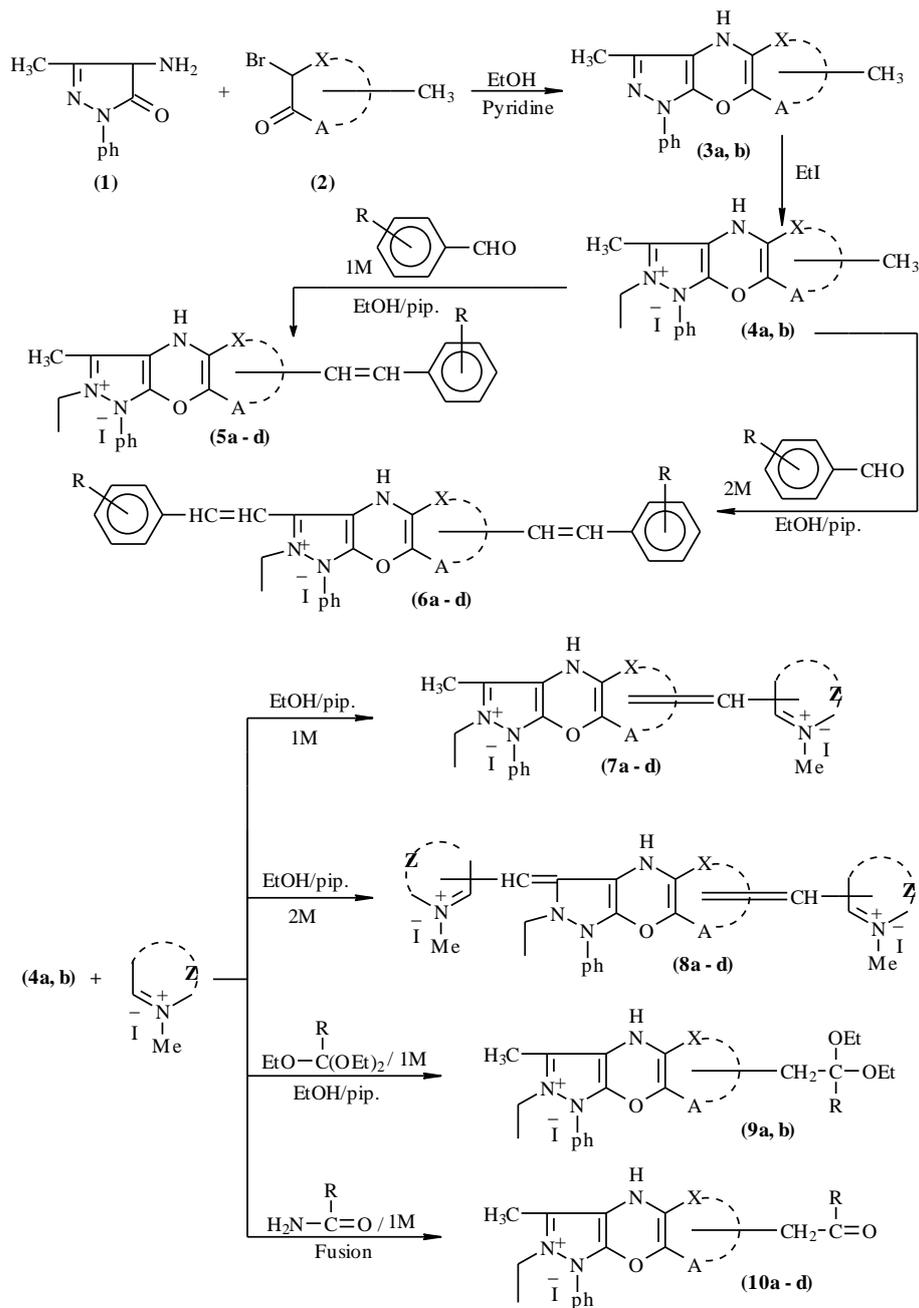
4-Cyanine dyes are biologically (antimicrobial) active dyes, and this can be evaluated through measuring their inhibition zone diameter against a number of bacterial and/or fungi strains. The cyanine dyes were thought to be better antimicrobial active when they give higher inhibition zone diameter against the tested bacterial and/or the fungi strains. Consequently, the antimicrobial activity of the cyanine dyes decrease when they give lower inhibition zone diameter against the tested bacterial and/or the fungi strains. So, we may say that the antimicrobial activity of one cyanine dye is stronger than the other one if the inhibition zone diameter against the tested bacterial and/or the fungi strains of the former one is higher than that of the latter one. In contrary, we may say that the antimicrobial activity of one cyanine dye is weaker than the other one if the inhibition zone diameter against the tested bacterial and/or the fungi strains of the former one is lower than that of the latter one. Studying the antimicrobial activity evaluation against a number of bacterial and/or fungi strains bears to have a great practical value in the case of cyanine dyes because the extensive uses and applications of these dyes as bactericidal (anti-bacterial strains) and/or as fungicidal (anti-fungi strains) in pharmaceutical (pharmacological) industry and/or in pharmacology.

5-Cyanine dyes are rich electronic transitions dyes, and this can be evaluated through investigating their electronic visible absorption spectra in 95 % ethanol solution. The dyes were thought to be better electronic transitions when they absorb light at higher wavelength bands (bathochromic shifted and/or red shifted dyes). Consequently, the electronic transitions of the dyes decreases when they absorb light at lower wavelength bands (hypsochromic shifted and/or blue shifted dyes). So, we may say that the electronic transitions of one cyanine dye is higher than the other one if the wavelength of the maximum absorption spectrum of the former one is longer than that of the latter one. In contrary, we may say that the electronic transitions of one cyanine dye is lower than the other one if the wavelength of the maximum absorption spectrum of the former one is shorter than that of the latter one. Studying the visible electronic transition absorption spectra in 95 % ethanol solution is very important in the case of cyanine dyes because the wide uses and applications of these dyes as photographic sensitizers in photographic material industry.

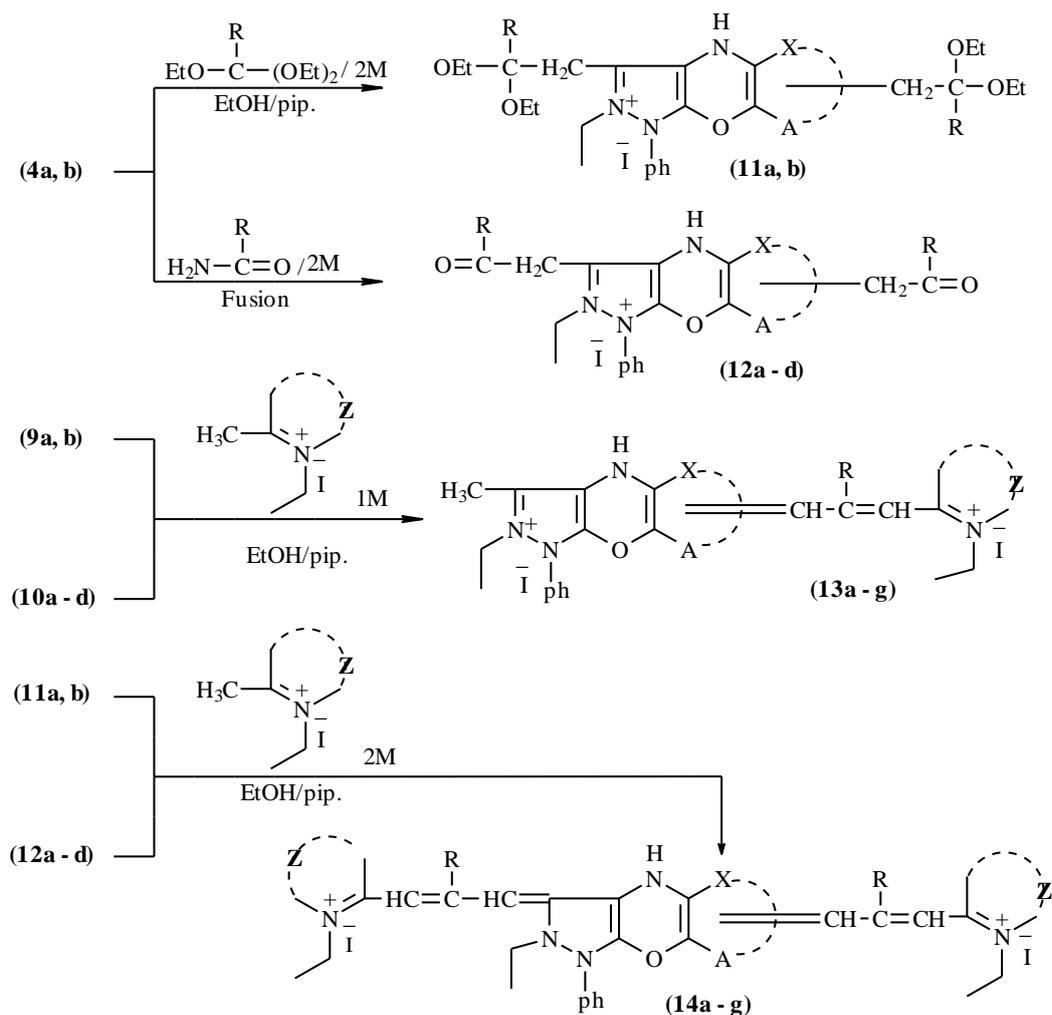
6-Cyanine dyes are anti-tumor and/or anti-cancer dyes, and this can be explained in the light of their extensive uses and applications in photodynamic therapy (PDT). Photodynamic therapy (PDT) is a new technique and/or method for treatment of cancer. Due to their excellent properties, cyanine dyes are used in light power treatment. Photodynamic therapy has many advantages compared with surgery chemotherapy and radiotherapy treatment in treating cancer. First of all, it can have special light sensitive materials accumulate in tumor selectively, which will not damage the body normal tissues cells. Secondly, only local anesthetic is needed which saves a lot of medical bills. Finally, the side effect is small, which does not cause other damage in the body. Because of its light selectivity and specificity, photodynamic therapy only damage tumor tissue without harming the body normal cells. Particularly, merocyanine dyes can distinguish some certain cells and selectively enter into cancer cells, then kill it as photosensitizers directly using for photodynamic therapy (PDT) or as radiation sensitizers for the treatment of solid tumors, where the affinity between cyanine dyes and tumor cells is much higher than that between cyanine dyes and normal cells. Merocyanine dyes are also used as antitumor drugs and combining PDT with drug therapy has become a tendency and will certainly promote the treatment of tumors.

2. Synthesis of Different Classes of Polyheterocyclic Cyanine Dyes

Styryl cyanines (5a-d), (6a-d), monomethine cyanine dyes (7a-d), (8a-d) and trimethine cyanine dyes (13a-g), (14a-g) incorporating bis pyrazolo-[2,3-b; 2',3'-b'] oxazine and/or pyrazolo [2,3-b]-oxazolo[2',3'-b']oxazine were prepared (Osman et al., 1997), Scheme (1).



Scheme (1)



Scheme (1) continue

Substituents in Scheme (1):

(3a, b): X(A)= 3[1-phenyl pyrazole] (a); X(A)= 6[oxazole] (b).

(4a, b): X(A)= 3[1-phenyl pyrazolium-2-yl salt] (a);

X(A)= 6[oxazolium-5-yl salt] (b).

(5a-d); (6a-d): X(A)= 3[1-phenyl pyrazolium-2-yl salt]; R= H(a), ρ .OCH₃ (b), ρ .NO₂ (c);

X(A)= 6[oxazolium-5-yl salt]; R= ρ .OCH₃ (d).

(7a-d);(8a-d): X(A)=3[N-ethyl pyrazole], Z= 1-methyl pyridinium-4-yl salt (a);

X(A)= 3[N-ethyl pyrazole], Z= 1-methyl quinolinium-4-yl salt (b);

X(A)= 3[N-ethyl pyrazole], Z= 2-methyl isoquinolinium-1-yl salt (c);

X(A)= 6[N-ethyl oxazole], Z= 1-methyl quinolinium-4-yl salt (d).

(9a, b); (11a, b): X(A)= 3[1-phenyl pyrazolium-2-yl salt], R= H (a);

X(A)= 6[oxazolium-5-yl salt], R= H (b).

(10a-d); (12a-d): X(A)= 3[1-phenyl pyrazolium-2-yl salt]; R= CH₃ (a),

CF₃ (b), C₆H₅ (c). X(A)= 6[oxazolium-5-yl salt], R= CH₃ (d).

(13a-g); (14a-g): X(A)= 3[N-ethyl pyrazole], R= H, Z= 1-ethyl pyridinium-2-yl salt (a);

X(A)= 3[N-ethyl pyrazole], R= H, Z= 1-ethyl quinolinium-2-yl salt (b);

X(A)= 6[N-ethyl oxazole], R= H, Z= 1-ethyl quinolinium-2-yl salt (c);

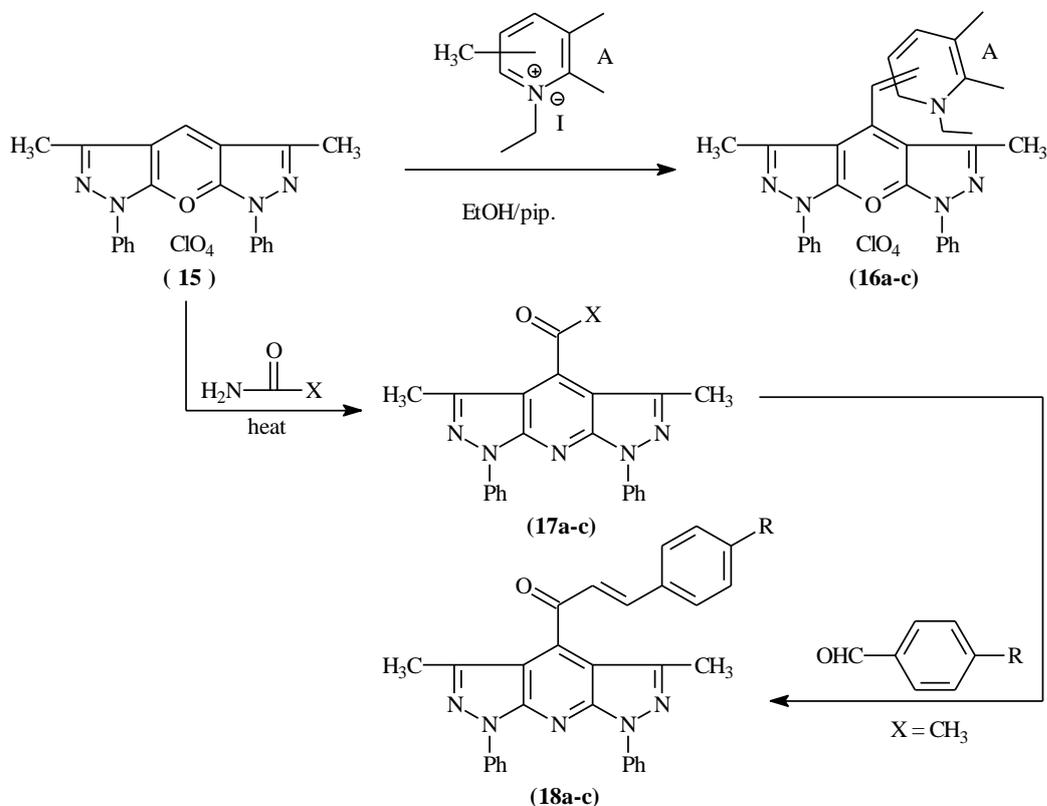
X(A)= 3[N-ethyl pyrazole], R= CH₃, Z= 1-ethyl quinolinium-2-yl salt (d);

X(A)= 3[N-ethyl pyrazole], R= CF₃, Z= 1-ethyl quinolinium-2-yl salt (e);

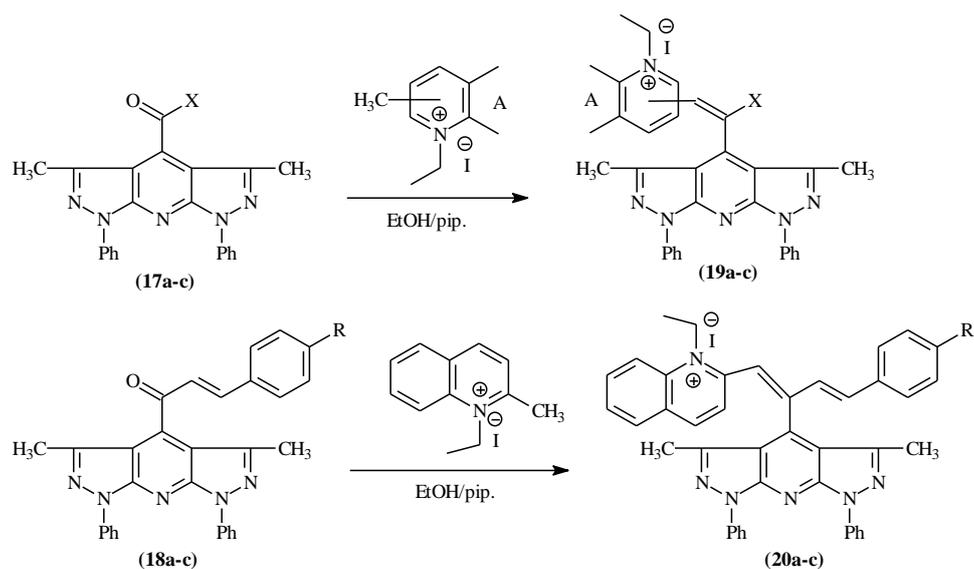
X(A)= 3[N-ethyl pyrazole], R= C₆H₅, Z= 1-ethyl quinolinium-2-yl salt (f);

$X(A) = 6[N\text{-ethyl oxazole}], R = \text{CH}_3, Z = 1\text{-ethyl quinolinium-2-yl salt (g)}$.

Monomethine, β -substituted dimethine and styryl cyanine dyes were synthesized using oxonium salts (El-Aal, et al., 2005), Scheme (2).



Scheme (2)



Scheme (2) continue

Substituents in Scheme (2):

(16a-c): A = 1-ethylpyridine-2-ium (a); 1-ethylquinoline-2-ium (b);
1-ethylpyridine-4-ium (c).

(17a-c): X = H (a); CH₃ (b); ph (c).

(18a-c): R = H (a); OH (b); NO₂ (c).

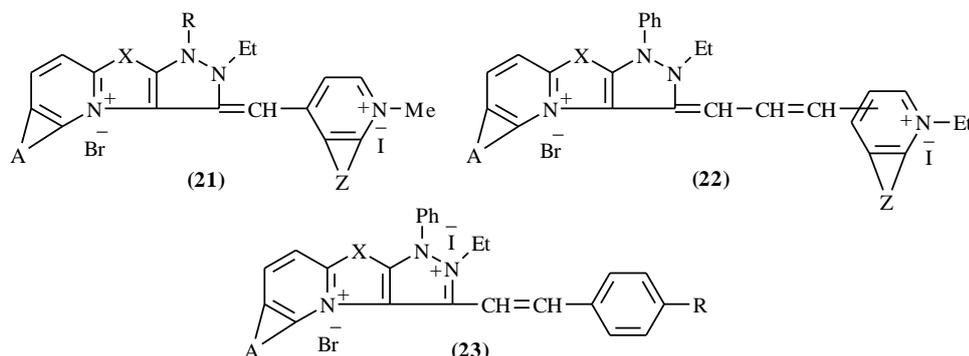
(19a-c): X = H, A = 1-ethylquinoline-2-ium (a);

X = CH₃, A = 1-ethylquinoline-2-ium (b);

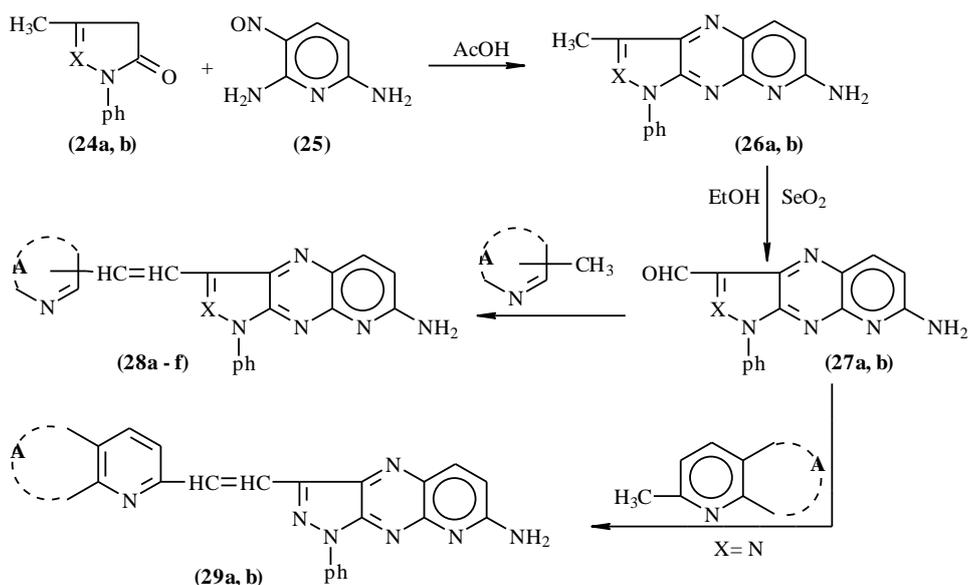
X = ph, A = 1-ethylquinoline-2-ium (c).

(20a-c): R = H (a); OH (b); NO₂ (c).

Monomethine cyanines (21, R = H, ph; X = NH, CH₂; A = H, C₄H₄; Z = H, C₄H₄), trimethine cyanines (22, X = NH, CH₂; A = H, C₄H₄; Z = H, C₄H₄) and styryl cyanines (23, R = H, OMe, NO₂; X = NH, CH₂; A = H, C₄H₄) were synthesized (Abu El-Hamd, 1996), Scheme (3).

**Scheme (3)**

Dimethine cyanines (28a-f) and their bases (29a, b), incorporating pyrazolo (3,4-d)-8-amino-1-azaquinoxaline moiety or its ethiodide, have been prepared (El-Maghraby, et al., 1988), Scheme (4).

**Scheme (4)**

Substituents in Scheme (4):(24, 26, 27): X= N(a); N⁺ – EtI⁻ (b).

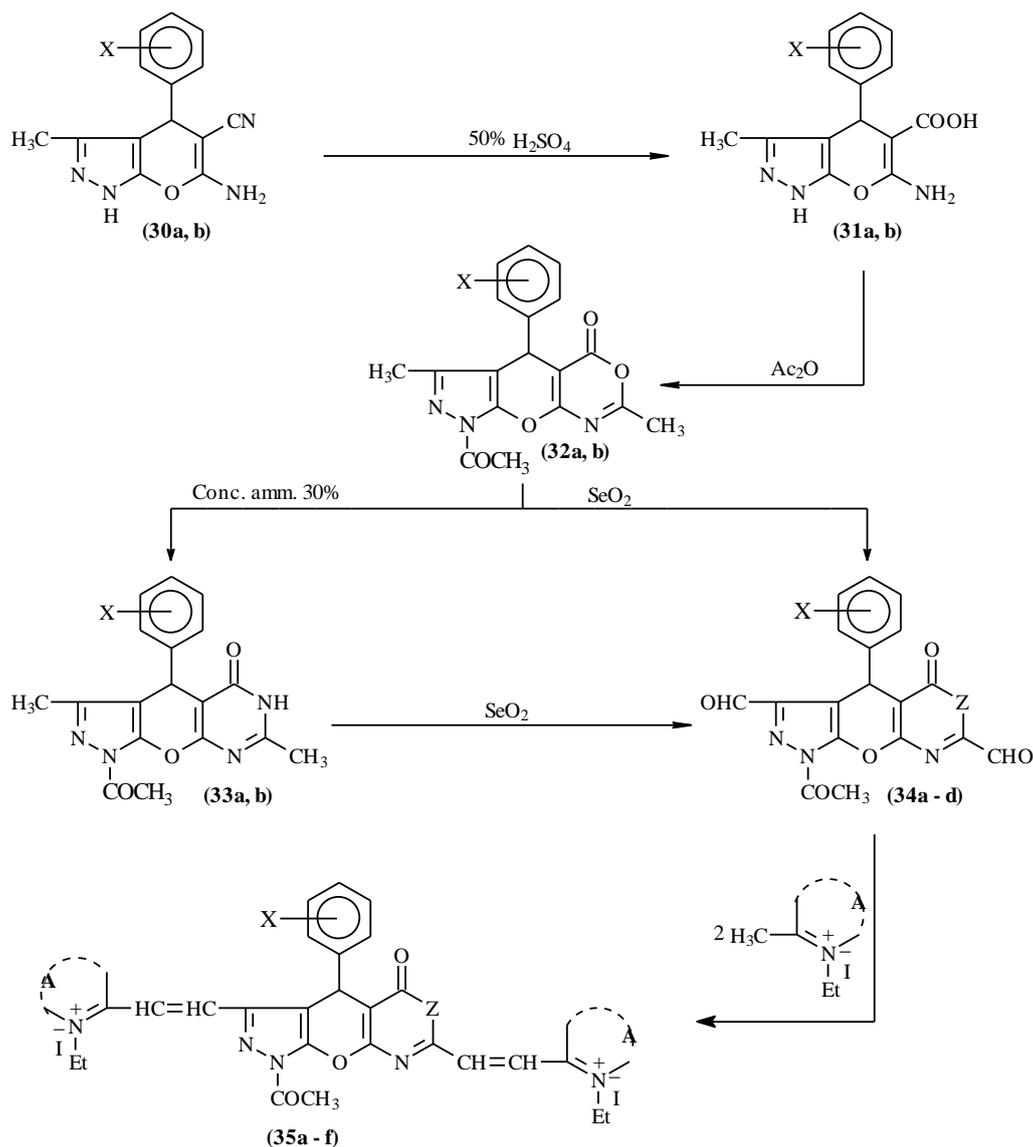
(28a-f): X= N, A= 1-ethyl pyridinium-2-yl salt (a);

X= N, A= 1-ethyl quinolinium-2-yl salt (b);

X= N, A= 1-ethyl pyridinium-4-yl salt (c);

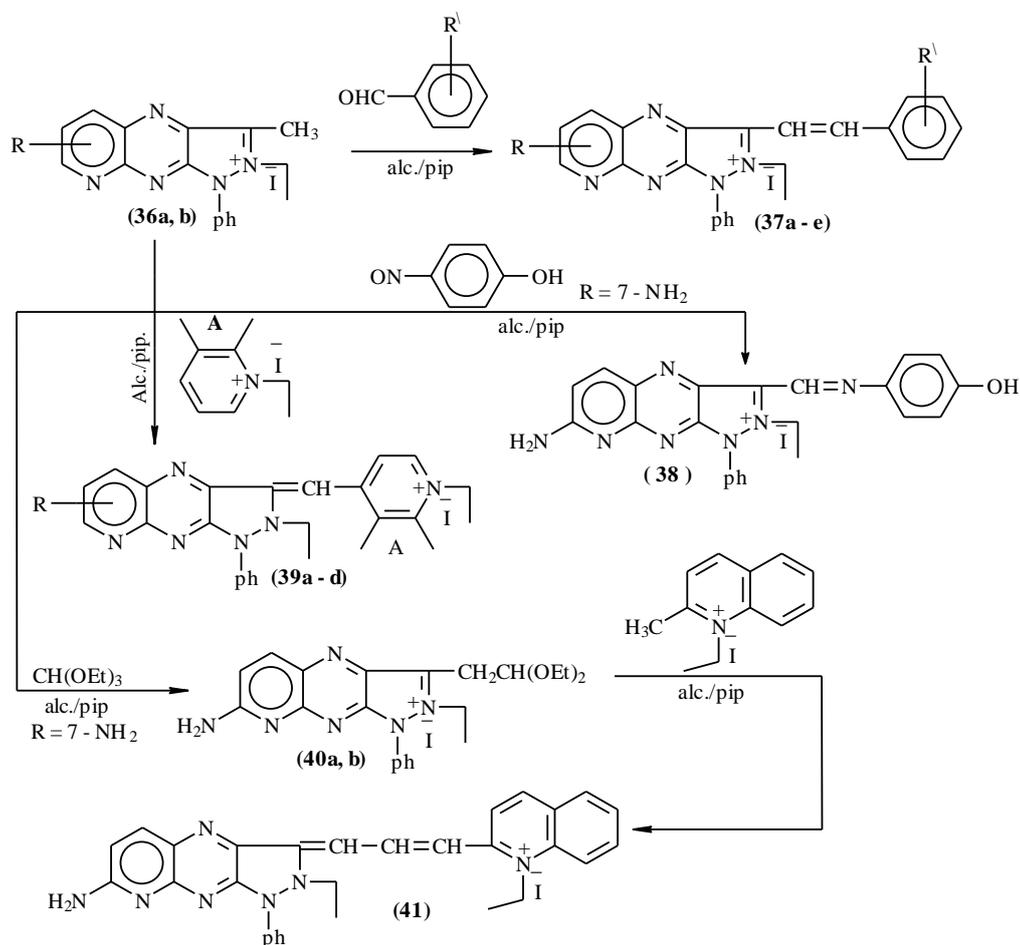
X= N⁺-EtI⁻, A= 1-ethyl pyridinium-2-yl salt (d);X= N⁺-EtI⁻, A= 1-ethyl quinolinium-2-yl salt (e);X= N⁺-EtI⁻, A= 1-ethyl pyridinium-4-yl salt (f).(29a, b): A= H(a); C₄H₄ (b).

Dicationic cyanine dyes containing pyrazolo pyrano-oxazone/ pyrimidine moiety have been prepared and their visible absorption spectra have been studied (El-Maghraby et al., 1991), Scheme (5).

**Substituents in Scheme (5):**(30a, b), (31a, b), (32a, b), (33a, b): X = *p*.Cl (a), *p*.NO₂ (b).(34a – d): X = *p*.Cl, Z = O (a); X = *p*.Cl, Z = NH (b);X = *p*.NO₂, Z = O (c); X = *p*.NO₂, Z = NH (d).(35a – f): X = *p*.Cl, Z = O, A = 1-ethyl pyridinium-2-yl salt (a);X = *p*.Cl, Z = NH, A = 1-ethyl pyridinium-2-yl salt (b);

- X = ρ .Cl, Z = O, A = 1-ethyl quinolinium-2-yl salt (c);
 X = ρ .Cl, Z = NH, A = 1-ethyl quinolinium-2-yl salt (d);
 X = ρ .NO₂, Z = O, A = 1-ethyl quinolinium-2-yl salt (e);
 X = ρ .NO₂, Z = NH, A = 1-ethyl quinolinium-2-yl salt (f).

A series of pyrazolo[4,5-b] pyrido[2,3-c] pyrazine cyanine dyes covering styryl, aza-styryl, mono- and tri- methine cyanines were synthesized via reaction of 3-methyl-1-phenyl pyrazolo [4,5-b] pyrido [2,3-c] pyrazine-2-ethyl iodide with active components (Khalafalla et al., 1993), Scheme (6).

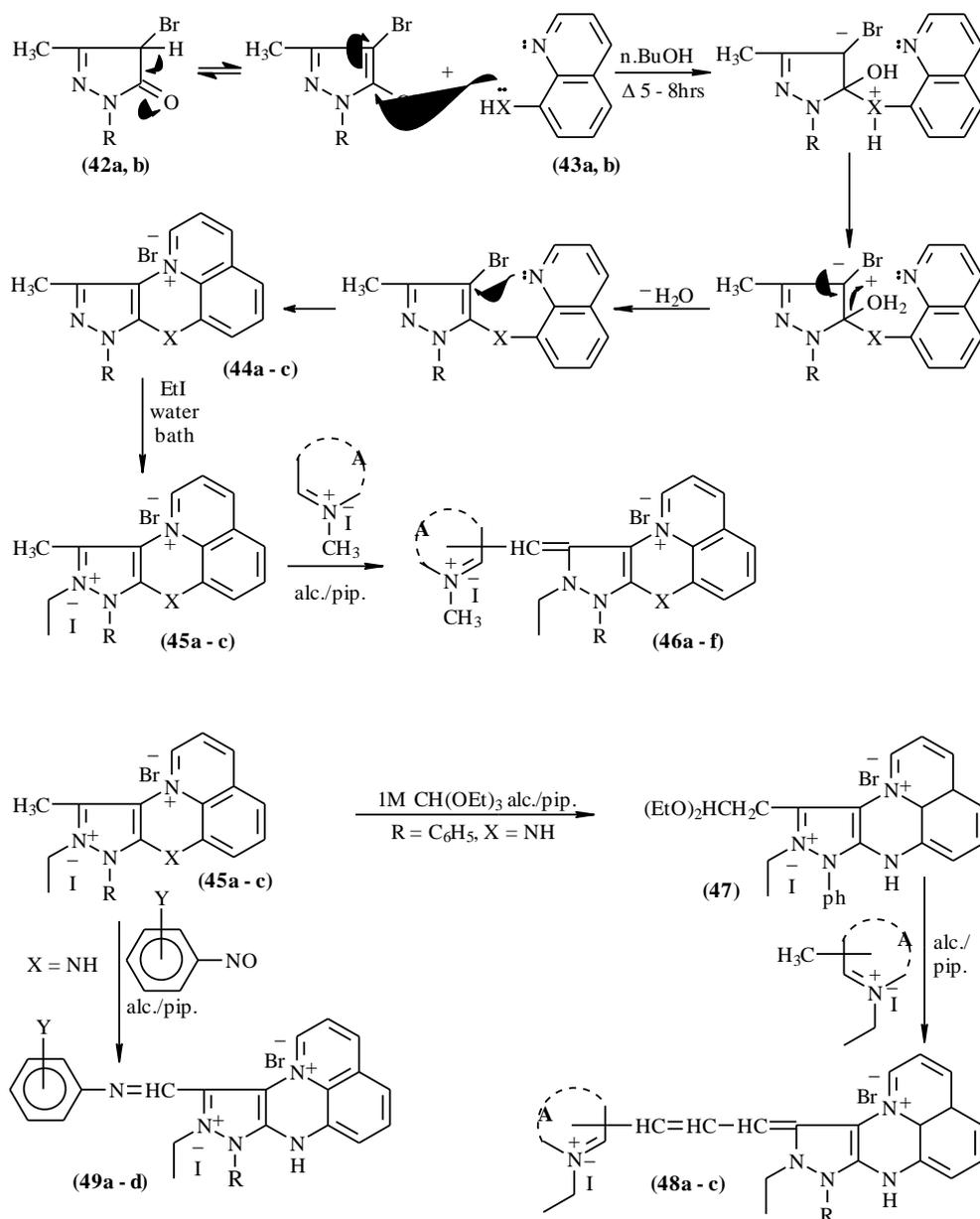


Scheme (6)

Substituents in Scheme (6):

- (36a, b): R = 6-Br (a); 7-NH₂ (b).
 (37a – e): R = 6-Br, R' = H (a), ρ .N(CH₃)₂ (b), ρ .NO₂ (c),
 R = 7-NH₂, R' = H (d), ρ .OH (e).
 (39a – d): R = 7-NH₂, A = 1-ethyl pyridinium-4-yl salt (a),
 R = 7-NH₂, A = 1-ethyl quinolinium-4-yl salt (b),
 R = 7-NH₂, A = 2-ethyl isoquinolinium-1-yl salt (c),
 R = 6-Br, A = 2-ethyl isoquinolinium-1-yl salt (d).

A number of mono-(tri-)methine and aza-methine cyanine dyes of pyrazolo [5,4-b] quinolino[a,b]-1,4-pyra-(oxa)-zinium bromide salts were prepared (Koraïem et al., 1999), Scheme (7).



Scheme (7)

Substituents in Scheme (7):

 (42a, b): R = H (a); C₆H₅ (b).

(43a, b): X = NH (a); O (b).

 (44a - c); (98a - c): R = C₆H₅, X = NH (a);

 R = C₆H₅, X = O (b); R = H, X = NH (c).

 (46a - f): R = C₆H₅, X = NH, A = 1-methyl pyridinium-4-yl salt (a);

R = H, X = NH, A = 1-methyl pyridinium-4-yl salt (b);

 R = C₆H₅, X = NH, A = 1-methyl quinolinium-4-yl salt (c);

 R = C₆H₅, X = O, A = 1-methyl quinolinium-4-yl salt (d);

 R = C₆H₅, X = NH, A = 2-methyl isoquinolinium-1-yl salt (e);

 R = C₆H₅, X = O, A = 2-methyl isoquinolinium-1-yl salt (f).

(48a - c): A = 1-ethyl pyridinium-2-yl salt (a);

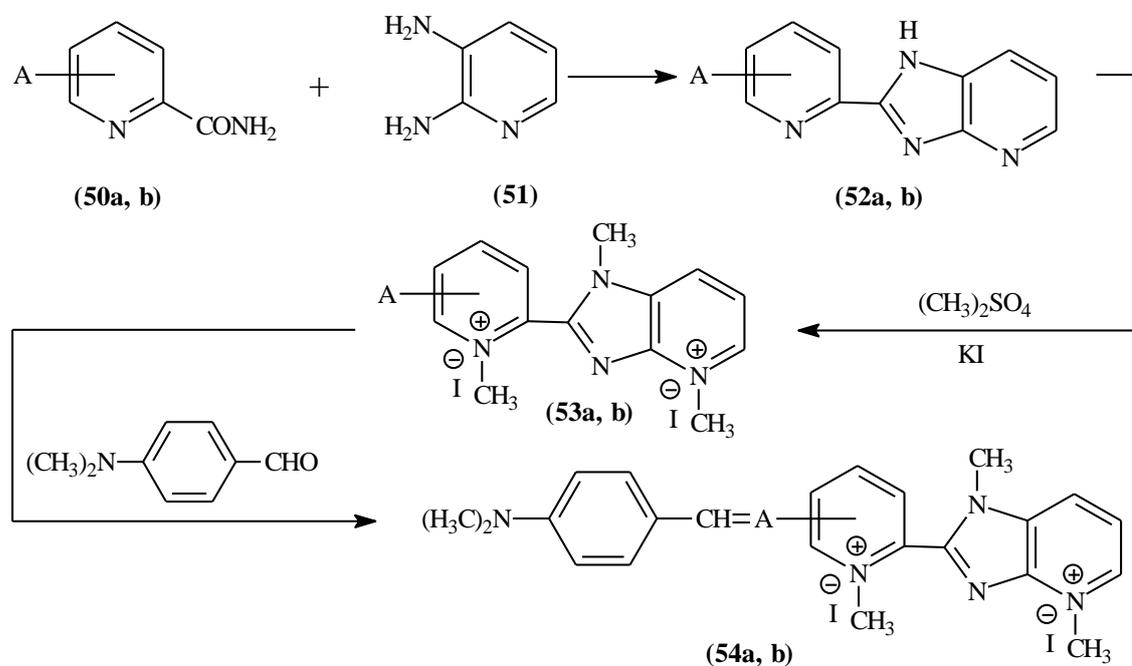
A = 1-ethyl quinolinium-2-yl salt (b);

A = 1-ethyl pyridinium-4-yl salt (c).

 (49a - d): R = C₆H₅, Y = 4.OH (a); R = H, Y = 4.OH (b);

R = C₆H₅, Y = 2.OH, 5,6-benzosubstituent (c);
 R = C₆H₅, Y = 2.OH, 3,4-benzosubstituent (d).

Savarino, et al., synthesized new styryl cyanine dyes by quaternization of 2[2(4)-methyl pyridyl]-imidazo[4,5-b]pyridine and further reaction with p.dimethylamino-benzaldehyde (Savarino et al., 1987), Scheme (8).



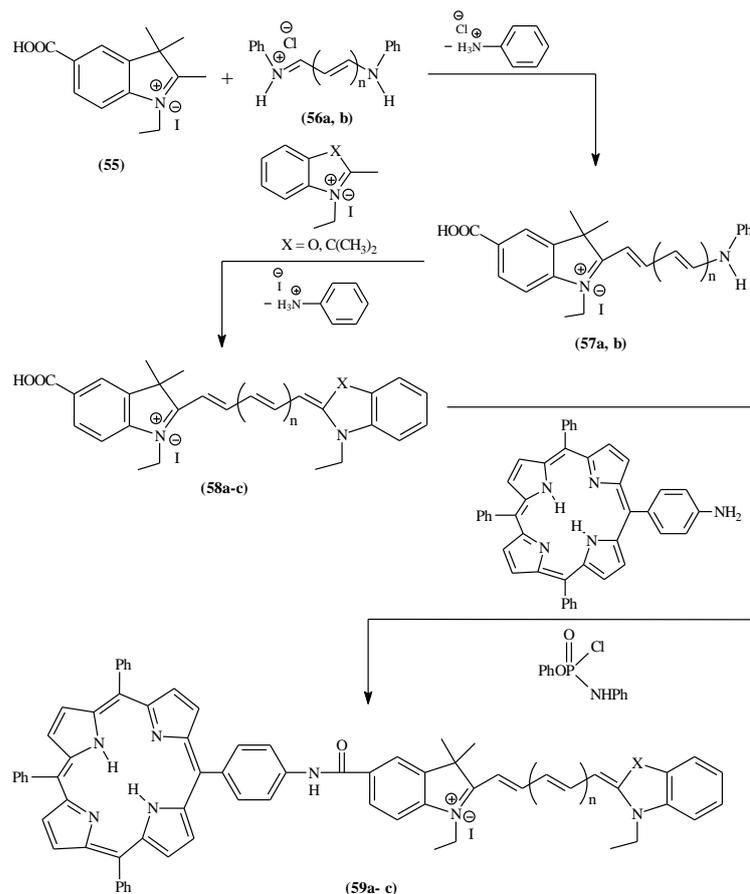
Scheme (8)

Substituents in Scheme (8):

(50a, b); (52a, b); (53a,b): A = 2-methyl (a); 4-methyl (b).

(54a, b): A = 2-methine (a); 4-methine (b).

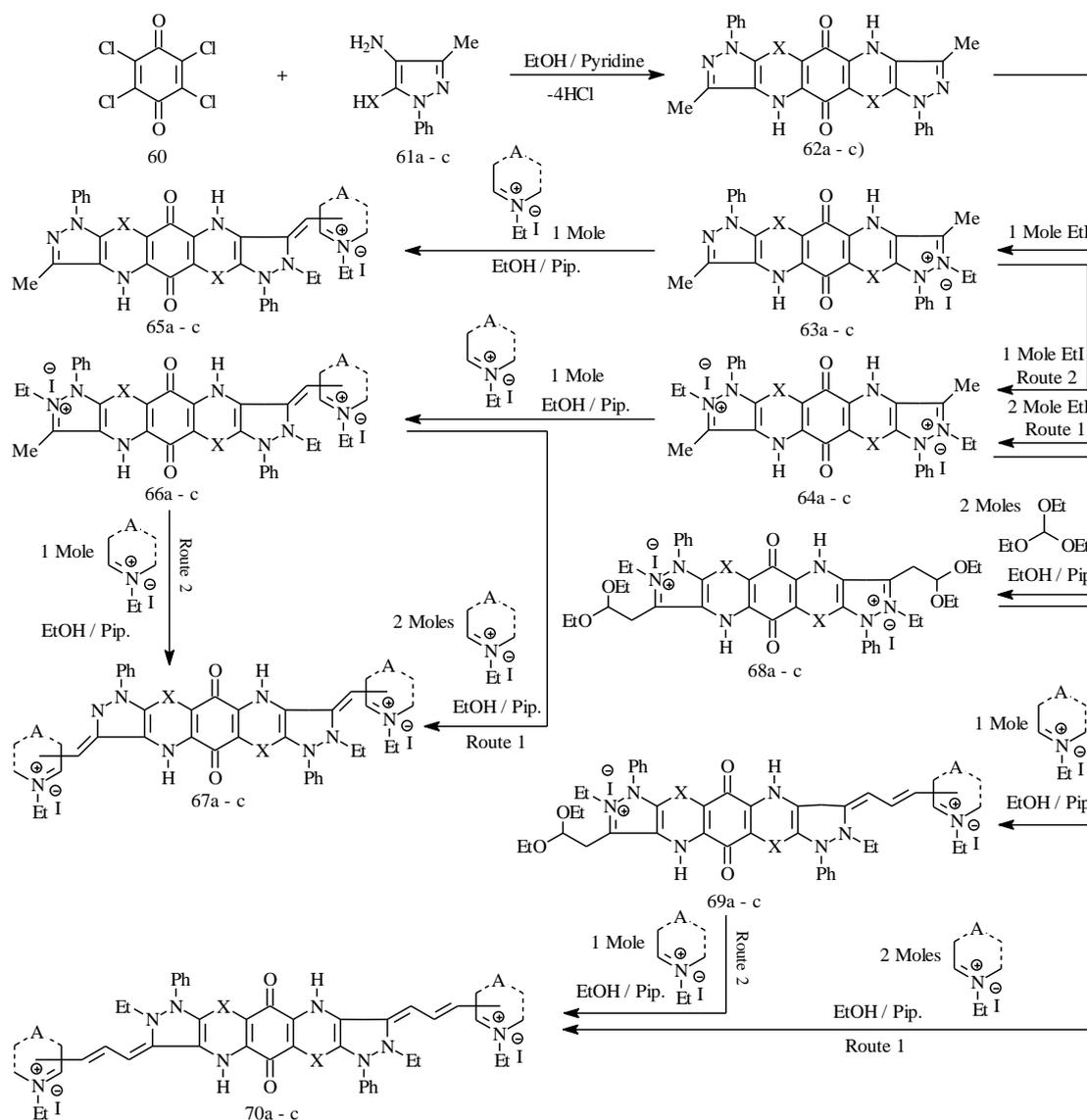
Lindsey, et al., prepared three members of a new class of photochemical model compounds containing a covalently-linked porphyrin and a cyanine dye (Lindsey et al., 1989), Scheme (9).



Scheme (9)

Substituents in Scheme (9):(56a, b); (57a, b): $n = 0$ (a); 2 (b).(58a - c); (59a - c): $X = O$, $n = 0$ (a); $X = C(CH_3)_2$, $n = 0$ (b); $X = C(CH_3)_2$, $n = 2$ (c).

Shindy, et al. prepared a series of cyanine dyes including monomethine cyanine dyes (simple cyanine dye) and trimethine cyanine dyes (carbocyanine dyes) incorporating benzo[2,3-b, 2',3'-b']bispyrazolo[4,5-b]-1,4-(oxa-, thia- and pyra-)zine-6,12-dione (Shindy et al., 2006), Scheme (10).



Scheme (10)

Substituents in Scheme (10):

(61a-c); (62a-c); (63a-c); (64a-c) & (68a-c): X = O (a); X = S (b); X = NH (c).

(65a-e); (66a-e) & (67a-e): X = O, A = 1-ethyl pyridinium-4-yl salt (a);

X = O, A = 1-ethyl quinolinium-4-yl salt (b);

X = O, A = 2-ethyl isoquinolinium-1-yl salt (c);

X = S, A = 1-ethyl quinolinium-4-yl salt (d);

X = NH, A = 1-ethyl quinolinium-4-yl salt (e).

(69a-g) & (70a-g): X = O, A = 1-ethyl pyridinium-2-yl salt (a);

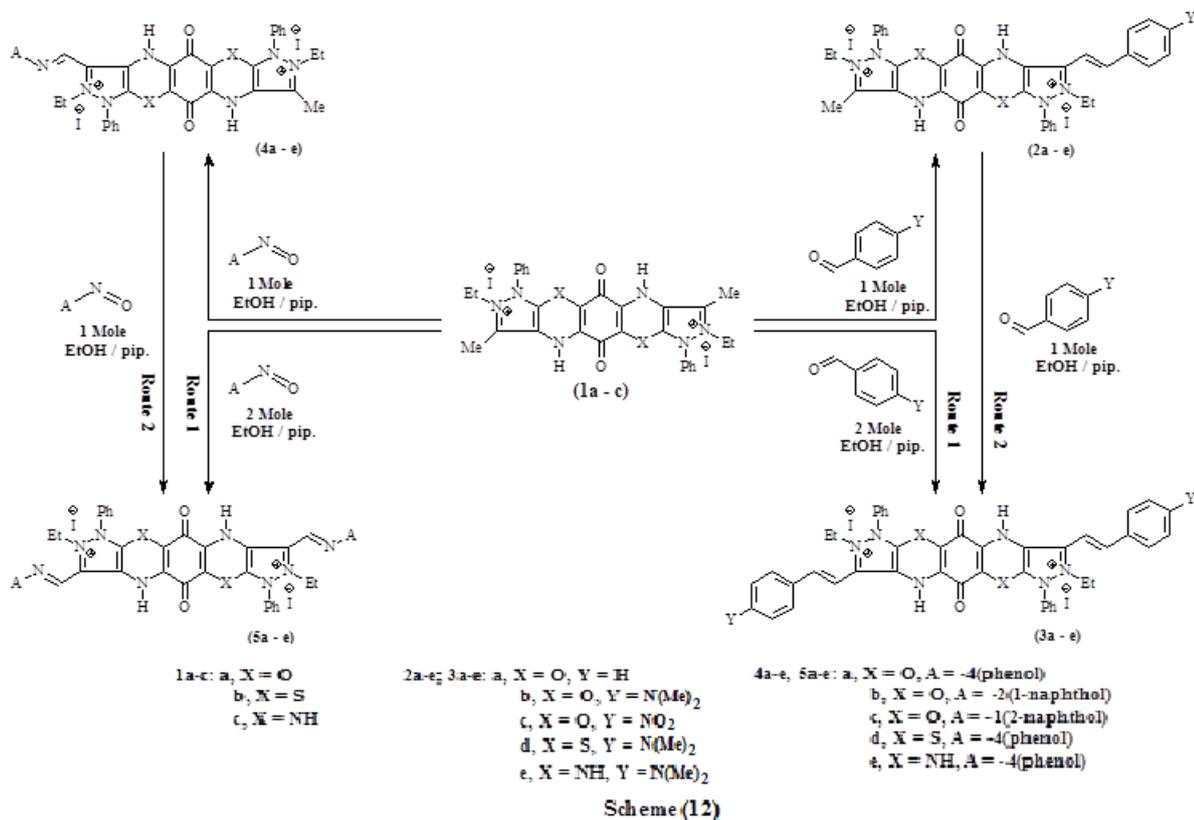
X = O, A = 1-ethyl quinolinium-2-yl salt (b);

X = O, A = 1-ethyl pyridinium-4-yl salt (c);

X = S, A = 1-ethyl quinolinium-2-yl salt (d);

X = NH, A = 1-ethyl quinolinium-2-yl salt (e).

Shindy synthesized a number of monomethine cyanine dyes, bis monomethine cyanine dyes, trimethine cyanine dyes and bis trimethine cyanine dyes having benzo[2,3-b; 2',3'-b']bis furo[3,2-d]pyrazole nuclei (Shindy, 2007), Scheme (11).

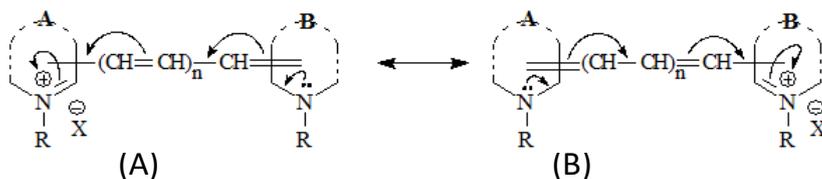


Scheme (12)

3. Conclusion

1. Cyanine dyes are comprised of two heterocycles containing nitrogen linked together by a conjugated polymethine chain. The heterocycles act as both electron donors and acceptors creating an push-pull system throughout the molecule, allowing for long wavelength absorption, Scheme (13).

2. The intensity of the colour of the cyanine dyes is illustrated according to suggested two mesomeric electronic transitions structures (two resonance forms) (A) and (B) producing a delocalized positive charges over the conjugated chromophoric group system of the dyes, Scheme (13).



(n = 0, 1, 2, 3; etc.); R=CH₃, CH₃CH₂;

X=I; A=Heterocyclic nucleus; B=Heterocyclic nucleus

**Structure and colour intensity illustration of cyanine dyes
Scheme (13)**

3. Modification of cyanine dyes structures can be carried out through the following:

a-The use of heterocycles with different hetero atoms.

b-The use of heterocycles with different substituents on the carbon skeleton.

c-The use of heterocycles with different substituents on the nitrogen atom of the heterocycles.

d-The use of heterocyclic with different ring size system (five membered ring, six membered ring, etc.)

e-The use of heterocyclic with different nuclear number (mono nuclear, bi nuclear and/or polynuclear).

f-The change and/or replacing the substituents in the meso substituted side chain of the polymethine bridge.

g-Increasing and/or decreasing conjugation by increasing and/or decreasing the number of methine (-CH=) units between the two heterocycles.

h-Increasing and/or decreasing conjugation by increasing and/or decreasing the number of aza-methine (-CH=N-) units between the two heterocycles.

i-Changing the type of the heterocyclic quaternary salt residue employed in the reaction.

j-Changing the linkage position of the heterocyclic quaternary salt residue employed in the reaction.

k-Increasing and/or decreasing the number of the electronic charge transfer pathways inside the dyes molecules.

l-Increasing and/or decreasing the planarity of the dyes molecules.

m-Entering and/or introducing of either electron donating groups and/or electron withdrawing groups inside the dyes molecules.

n-Increasing and/or decreasing the number of the basic centers (electron pushing centers) inside the dyes molecules.

4. This review paper is recommended for chemists and researchers in the field of heterocyclic and/or cyanine dyes chemistry.

5. This paper review is recommended to all who are keen to have and know different methods in the synthesis of various classes of polyheterocyclic cyanine dyes and/or to get some basic applications, properties and characterization in the chemistry of cyanine dyes.

6. Because cyanine dyes have multi purposes uses and applications in various fields and different research area, this review paper is recommended not only for heterocyclic and/or cyanine dyes chemists but also for other scientists in other fields like biology, biotechnology, biochemistry, physics, engineering, pharmacology and medicine.

7. This review paper is recommended for all whom interested in the light absorbing systems in their research, labeling of biomolecules and/or in the synthesis and characterization of complex organic compounds.

8. This paper review is recommended to anyone interested in the subject, to chemistry libraries and also for the personal bookshelves of every organic heterocyclic and cyanine dyes chemist.

4. Current future development

The current and the future research developments aim to provide novel synthetic methods for the preparation of different classes of highly antimicrobial active, Anti-tumour, p-H sensitive, highly photographic sensitizers, non toxic, high stability, light fastness, near IR (Infrared), fluorescent, anti corrosion, strong labelled DNA and extra conjugated cyanine dyes. Such as oxadiazine cyanine dyes, thiazole cyanine dyes, metal stabilized cyanine dyes, pentamethine cyanine dyes, heptamethine cyanine dyes, nonamethine cyanine dyes, undecamethine cyanine dyes and tridecamethine cyanine dyes.

Also, the current and/or the future research developments aimed to provide new, novel and/or patent review papers in the field of color, dyes and pigments chemistry. The aimed review papers will covers and/or includes topics like the origin of color, the relation between color and constitutions, synthesis of dyes, properties of dyes, classification of dyes, uses and/or applications of dyes. Also, additional important topics for the current and/or the future research developments for the aimed review papers will includes methine cyanine dyes, hemi and/or styryl cyanine dyes, merocyanine dyes, apocyanine dyes, monoheterocyclic cyanine dyes, biheterocyclic cyanine dyes, polyheterocyclic cyanine dyes, six membered heterocyclic cyanine dyes, five/six membered heterocyclic cyanine dyes, five membered heterocyclic cyanine dyes and benz(naphth)/five membered heterocyclic cyanine dyes.

5. Conflict of interest

There is no conflict of interest.

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