Expediting research in Dye - Surfactant interaction: An aid to quick access to knowledge on properties of azodye - An approach

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Abstract

The interaction of twenty three dyes with four surfactants was studied by UV absorption spectroscopy. Out of the ninety two combinations tried, different observations were noted. They include bathochromic, hypsochromic, hyperchromic and hypochromic shifts and change of pH. Shift of the wavelength value observed ranged from 0 to 89 nm for various combinations and change of pH from a maximum of about 6.85 to a minimum of about 3.80. Five dyes are recommended to be used with all the four surfactants. Another five dyes were found suitable with three surfactants. Two dyes are found useful for two surfactants. There are also few single combinations of dye-surfactants which are noted. Overall forty seven combinations were found satisfactory out of ninety two. On basis of change of pH use of tween 80 with all the twenty three dyes is preferred. These readymade observations will be of help to the researchers in selecting dye-surfactant combinations by cutting on the money and time spent for finding them through experiment.

Keywords: Dye-surfactant interaction, Azo dyes, UV-Spectrophotometry, Anionic dye, Cationic dye.

Abbreviations: Acid black-1 (Ab-1), Chloro phenol red (Cpr), Eosin yellow (Ey), Indigocarmine (Ic), Light green (Lg), Malachite green (Mg), Methyl orange (Mo), Methyl violet-2B (Mv-2B), Methylene blue (Mb), Naphthol blue black (Nbb), Phenol red sodium salt (Prs), Victoria blue-B (Vb-B), Reactive red-120 (Rr-120), Reactive yellow-84 (Ry-84), Trypan blue (Tb), Nitrazine yellow (Ny), Brilliant crocein (Bc), Methyl blue (Mlb), Rhodamine-B (Rh-B), Alizarin red-S (Ar-S), Alizarin cyanine green (Acg), Acid yellow-17 (Ay-17) and Acid green-16 (Ag-16).

1. INTRODUCTION

In analytical chemistry surfactants are used in spectrophotometry and fluorimetry. Dye surfactant - interactions play an important role in various dyeing processes, metal ion determination, photosensitization and biochemistry. The choice of the surfactant is important in the dye separation process. Addition of small quantity of surfactant accelerates the rate of dye adsorption into fibres in textile industry. This is carried out on the basis of interaction of the surfactant with dye. The electronic absorption spectra of some dyes may display new bands in presence of surfactant [1]. If the interaction between the dye and surfactant is strong, then the spectral changes observed are also more. These changes (absorption spectra in visible region) of the dye on addition of different concentration of surfactant leads to attainment of (a) equilibrium between micelles and surfactant monomers, (b) Premicellar complex of dye surfactant, (c) dye particles penetrated into micelles, (d) formation of ion-pairs and (e) induced self-aggregation of dye.

Every dye has a characteristic wavelength at which absorbance of the dye solution shows maximum sensitivity to acid-base ratio. The pHis a measure of H^+ ion concentration pKa, the acid dissociation constant helps to predict what a molecule may do at a specific pH (whether it can donate or accept a proton). Various techniques are employed to observe this change. They are conductometry [2-5], voltametry [6], potentiometry [7-8] and spectrophotometry [9-12]. The most widely used one among them is the spectrophotometric method [13-14]. First a wavelength is chosen then the surfactant can be added and the effect can be monitored. The change of acid-base equation of the molecule may also be utilized to determine cmc the (critical micelle concentration) of the surfactant.

Acid black - 1 is an anionic acid dye with a blue-black colour. Chloro phenol redis an indicator dye that changes color from yellow to violet as the pH changes from 3.8 to 6.2. Hence, this is a pH indicator. It is used as an optical transducer of cholinesterase inhibition by analyses. Eosin yellow is orange coloured belonging to xanthene group. It finds applications like solvent polarity determination, lasers, cmc determination and characterization of super conductors. Indigo carmine dye is an anionic one used as a redox indicator. It has importance in the field of drug, food and cosmetic industry. It is used to detect amniotic fluid leaks in obstetric surgery. Light green is used in histology for staining collagen in North America. This was once used as green food colourant. Malachite green is used as antimicrobial in aquaculture and also for materials like leather, silk and paper. Additions of anions have no effect on the colour. Methyl orange is used in laboratory as common indicator. Methyl violet- 2B cationic dye is normally used as a biological stain. It is harmful if inhaled, swallowed or absorbed through skin. Methylene blue cationic dye is used as a medication and a dye. It is mainly used to treat methemoglobinemia. Naphthol blue black dye is used for protein and nucleic acid stain in SDS - PAGE (Sodium dodecyl sulphate - Polyacrylamide gel electrophoresis) gels. Phenol red sodium saltdye is a suitable pH indicator. It is used commonly for preparation of phosphate buffer saline (PBS) with phenol red for microfluidic assay for simultaneous culture of multiple cell types. Victoria blue-B dye finds application as a nuclear stain in cytology, histochemical application and quantitative determination of phospholipids. Reactive red-120 dye mainly used for cotton, viscose fiber, wool, nylon and polyester dyeing. These dyes have good fastness properties because of bonding that occurs during dyeing. Reactive yellow-84 dye is used for colouring cotton blended fabric, polyester and rayon blended fabric. They have no side effects hence they are used widely. Trypan blue azo dye is used as dye stuff. It is a direct dye for cotton textiles. It also finds wide usage in vital stain to selectively colour dead tissues or cells blue. Nitrazine yellow has been used in dye-protein binding assay. For example, the dye is used to test the degree of composition of meat. Brilliant crocein dye is used mainly for dyeing of silk, wool, paper and leather. They are also added to colour plastic wood, medicine and ink. Methyl blue is finds application in staining of histology, staining collagen blue in tissue sections. Fungal cell walls are also stained by methyl blue. Rhodamine-B is often used as a tracer dye. The dye can fluoresce and can be detected easily and inexpensively. It is also used in flow cytometry and fluorescence microscopy. Alizarin red-S is anthraquinoid dye forming anionic moiety finds use in checking calcium deposits in osteogenic culture. It is also used to study carbohydrate boronic acid interactions. Alizarin cyanine green dye is derived from quinizarin which dyes wool and mordanted silk. Acid yellow-17 dye is mostly used for wool in strong acid dye in bath dyeing and silk dyeing in acetic acid bath. It can also be used in dyeing leather and paper. Also, they can be used in paint, medicine and shading of cosmetics. Acid green-16 dye is most suitable for leather finishing, wood, stains, textile dyeing, paper, plastic, nylon, wool silk, carpet, detergents and pharmaceuticals.

The most commonly used method to study the properties of surfactants is from different phases via self assembly in spectrophotometry method. The researchers have to try their interaction with individual dyes which takes a lot of time. The aim of the present study is to pre-evaluate seven cationic and sixteen anionic dyes regarding their suitability for interaction with surfactants and present the data which can help the researchers to choose a dye, without going through the time consuming screening process.

2. EXPERIMENTAL

2. 1. Materials and methods

All the chemicals were purchased from Sigma Aldrich and used as such. Twenty three dyes were taken under investigation. Four surfactants F127 (407 Poloxamer), F108 (338 Poloxamer), P123 (403 Poloxamer) and Tween 80 (Polysorbate 80) were chosen. The dye solutions were prepared to a concentration of 1×10^{-3} M and then diluted to yield the optical density between 0.8 to 1.4 for spectrophotometry studies. The same solution was used for studying the pH. The surfactant concentration used for this purpose was 5% which was well above cmc of the four surfactants.

2.1.1. Spectral analysis

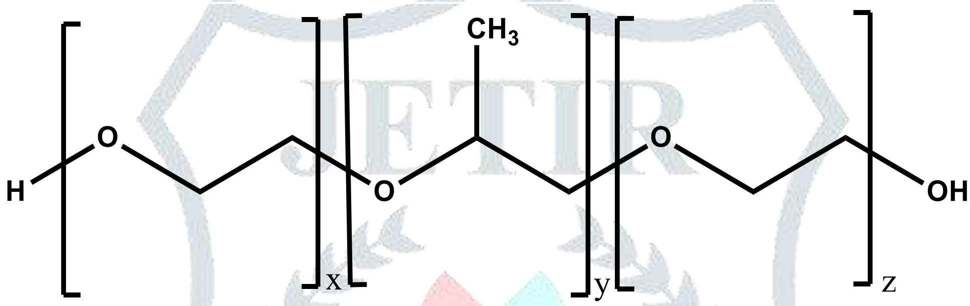
Absorption measurements were carried out using Shimadzu UV-2600 PC Probe Ver.1.03 Spectrophotometer. The concentration of dye was kept constant during the course of study. Each dye was tested with four surfactants individually and their spectral measurements were recorded. The pH study of the neat dye and dye-surfactant combination was done. Dyes and surfactants were prepared in triple distilled water. All measurements were taken in triplicate to ensure accuracy.

3. RESULTS AND DISCUSSION

3.1. Spectral studies

On addition of surfactant to particular dye different kinds of spectral changes are possible. The change can be bathochromic (red shift), hypsochromic (blue shift), hyperchromic or hypochromic (decrease) in absorbance type. Bathochromic shift is observed commonly due to change in the environmental conditions, such as solvent polarity. Hypsochromic shift is due to a change of spectral band position. Hyperchromic and hypochromic shifts are generally influenced by concentration of chromophore. We have analysed the data and presumed that a shift of 5 nm or more is considered as suitable combination and less than it is not fit for the dye-surfactant combination. The results are presented in **Table 1-3** and **Fig. 1-4.**

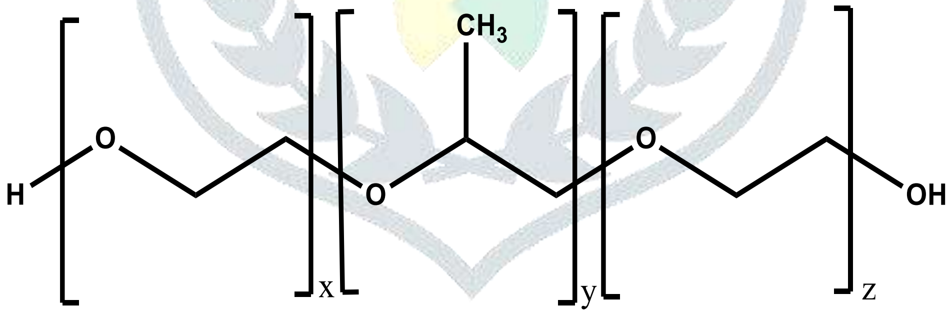
Table 1 presents the absorbance at wavelength for twelve dyes with four surfactants. **Table 2** shows the values for eleven dyes with four surfactants. **Table 3** displays the changes occurring due to the addition of surfactant viz. shift of wavelength and the change in pH. **Fig. 1** presents the group spectra for Acid black-1 (Ab-1), Chloro phenol red (Cpr), Eosin yellow (Ey), Indigocarmine (Ic), Light green (Lg) and Malachite green (Mg) with four surfactants. The second group of spectra for Methyl orange (Mo), Methyl violet-2B (Mv-2B), Methylene blue (Mb), Naphthol blue black (Nbb), Phenol red sodium salt (Prs) and Victoria blue-B (Vb-B) are shown in **Fig.2.** The third group of spectra is displayed in **Fig. 3.** They are Reactive red-120 (Rr-120), Reactive yellow-84 (Ry-84), Trypan blue (Tb), Nitrazine yellow (Ny), Brilliant crocein (Bc) and Methyl blue (Mlb). The spectra of dyes Rhodamine-B (Rh-B), Alizarin red-S (Ar-S), Alizarin cyanine green (Acg), Acid yellow-17 (Ay-17) and Acid green-16 (Ag-16) are presented in **Fig. 4.** All these spectra are indicative of dye-surfactant interaction. The structures of four non-ionic surfactants **(Fig. 5)** (i) F127, (ii) F108, (iii) P123 and (iv) Tween 80 are presented below.



(PEO_{99}-PPO_{67}-PEO_{99})

(Pluronic F127)

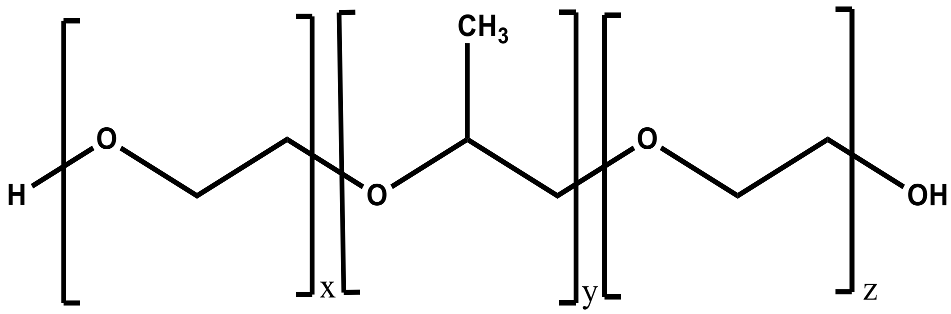
Figure 5. (i) Structure of Pluronic F127.



(PEO_{132}-PPO_{50}-PEO_{132})

(Pluronic F108)

Figure 5. (ii) Structure of Pluronic F108.



(PEO_{20}-PPO_{70}-PEO_{20})

(Pluronic P123)

Figure 5. (iii) Structure of Pluronic P123.

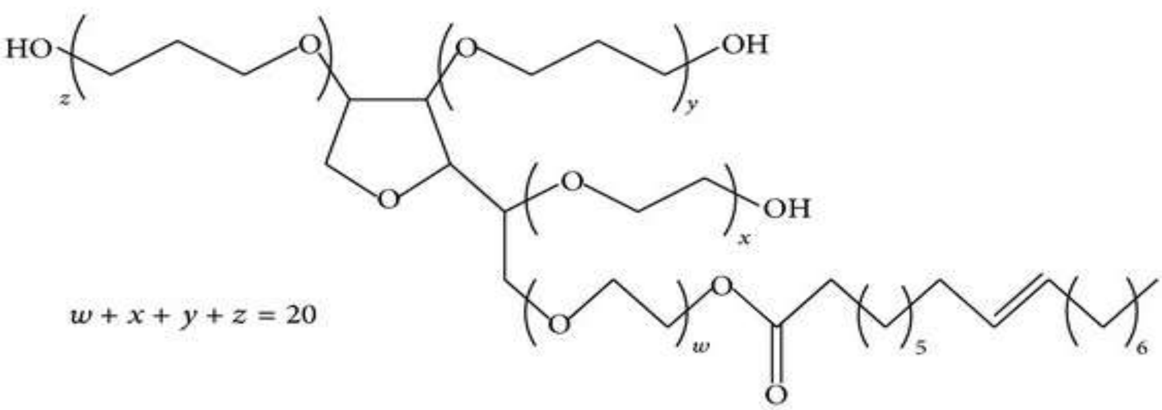


Figure 5. (iv) Structure of Tween 80.

3.1.1. Acid black (Ab-1)

The molecular formula is $C_{22}H_{14}N_6Na_2O_9S_2$. It showed absorption maxima at 615 nm in aqueous medium [15-19]. It displayed red shift on addition of all the four surfactants. The change in wavelength was 5, 7, 8 and 8 nm respectively for F127, F108, P123 and Tween 80 surfactants. The change in pH was not very remarkable except for surfactant Tween 80. The absorbance at wavelength was seen to decrease with F127, F108 and increase with P123 and Tween 80. The dye-surfactant interaction was moderate. Hence, they are suitable combinations for absorption studies.

3.1.2. Chloro phenol red (Cpr)

Its molecular formula is $C_{19}H_{12}Cl_2O_5S$. It showed three absorption peaks at 271, 439 and 582 nm, out of which 439 nm was the prominent peak which is described here [20]. By adding surfactants it got blue shifted for surfactants F127, F108, P123 and there was no shift with surfactant Tween 80. There was marked change in pH on addition of surfactants. Absorbance at wavelength was also observed to increase in all four surfactants. Since there was shift of 7, 2, 2 and 0 nm, the last three are not suitable for UV-absorption studies, this dye can be used for surfactant F127 alone (since shift is above 5nm).

3.1.3. Eosin yellow (Ey)

It has molecular formula is $C_{20}H_6Br_4Na_2O_5$. It showed two absorption maxima at 517 and 542 nm [21-27]. We have considered 517 nm peak. After adding surfactants there was blue shift by 9, 4, 17 and 16 nm for F127, F108, P123 and Tween 80 respectively. Absorbance of wavelength was seen to decrease for all four surfactants. The pH change due to addition of surfactant was not prominent. Except surfactant F108 other three are suitable combinations for absorption studies with this dye.

3.1.4. Indigocarmine (Ic)

Its molecular formula is $C_{16}H_8N_2Na_2O_8S_2$ [28-29]. In aqueous solution it shows a maximum at 607 nm. Surfactant interaction leads to a red shift by 4, 4, 3 and 5 nm for F127, F108, P123 and Tween 80 respectively. Absorbance at wavelength was observed to decrease in all four surfactants and it was very small with surfactant P123. The pH change was marginal for surfactant F127, F108 but substantial for P123 and Tween 80. This dye is suitable for surfactant Tween 80 only.

3.1.5. Light green (Lg)

The molecular formula is $C_{37}H_{34}N_2Na_2O_9S_3$. In aqueous medium it shows absorbance maxima at 638 nm [30]. On addition of surfactants it got red shifted by 3, 2, 3 and 1 nm for F127, F108, P123 and Tween 80 respectively. There was little change in pH of the solution. The wavelength absorbance value became less with F127, P123, Tween 80 and more with surfactant F108. All four surfactants have weak interaction with this dye, hence are not suitable for spectral studies.

3.1.6. Malachite green (Mg)

The intense green colour of the cation results from a strong absorption band at 615 nm in aqueous solution [31-33]. After adding surfactant a red shift was observed with 4, 2, 6 and 10 nm for F127, F108, P123 and Tween 80 surfactant respectively. There was slight change in pH of the solution. This dye had an interesting finding with two surfactants. On addition of surfactant F127 and P123 to the dye, the green colour completely changed to colourless solution. This is obvious from the wavelength absorbance value in Table 1 which shows that there is increase in wavelength absorbance for F108 and Tween 80 and decrease to a very small value with F127 and P123 surfactant. This infers that this dye has highly oxidative character in presence of F127and P123, hence not suitable to be used for absorbance studies. However, F108 and Tween 80 are acceptable for observing dye-surfactant interaction.

3.1.7. Methyl orange (Mo)

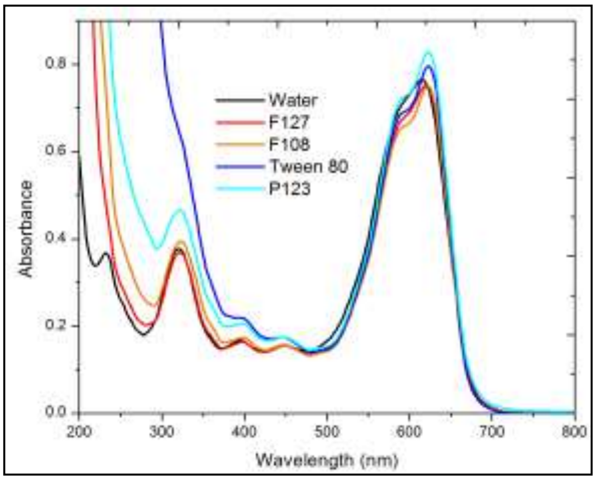
The molecular formula is $C_{14}H_{14}N_3NaO_3S$. This cationic azo dye displays two peaks in aqueous medium. There are two peaks; one at 272 nm and the other at 463 nm [34-37]. The latter band is more prominent hence discussed here. The wavelength of maximum absorption (λ_{max} = 463 nm) undergoes a shift upon addition of surfactants F127, F108, P123 and Tween 80. There was blue shift of 35, 1, 38 and 39 nm for the above series. The observed pH change was small for F127, F108 and P123 and more for surfactant Tween 80. The absorbance at wavelength was seen to reduce for F127 and increase with F108, P123 and Tween 80 respectively. Except surfactant F108 other three are recommended for interaction with this dye.

3.1.8. Methyl violet -2B (Mv-2B)

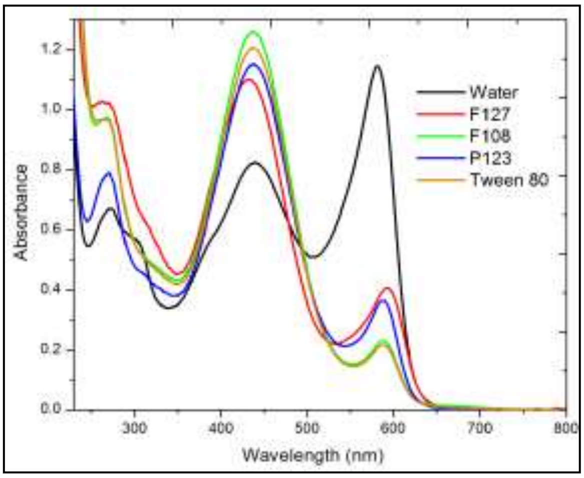
It has the molecular formula $C_{25}H_{30}ClN_3$. It shows two peaks at 297 and 575 nm [39-41]. The discussion is confined to 575 nm peak only. The wavelength shows a red shift on addition of surfactants. The shifts are 5, 4, 8 and 9 nm for surfactants F127, F108, P123 and Tween 80 respectively. The change in pH was more for surfactant F127 and F108 compared to P123 and Tween 80. The absorbance at wavelength was observed to increase with F127, F108 and decrease with surfactants P123 and Tween 80. This dye is acceptable for studying the spectral change in absorbance with the surfactants above except F108.

3.1.9. Methylene blue (Mb)

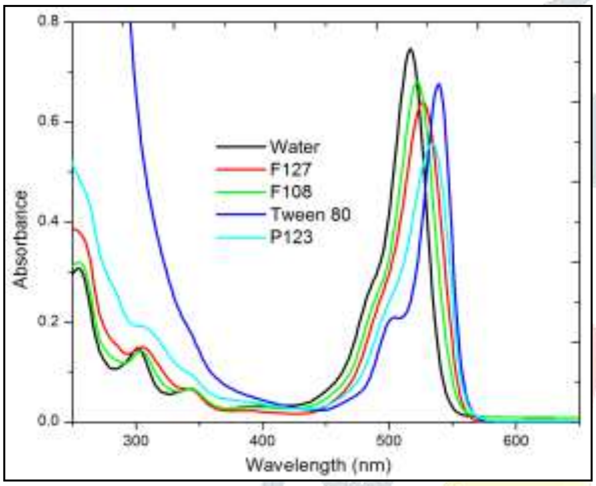
It has molecular formula $C_{16}H_{18}ClN_3S$. In the UV- absorption spectra there are two peaks observed at 292 and 663 nm [1, 42-45]. We have taken the second peak because of its high absorbance value. Surfactant addition leads to red shift by 1 nm in each case. There was little change in the absorbance at wavelength. The pH change was negligible for F127, F108 and P123 but, it was significant for surfactant Tween 80. This dye is only suitable with the surfactant Tween 80 for interaction.



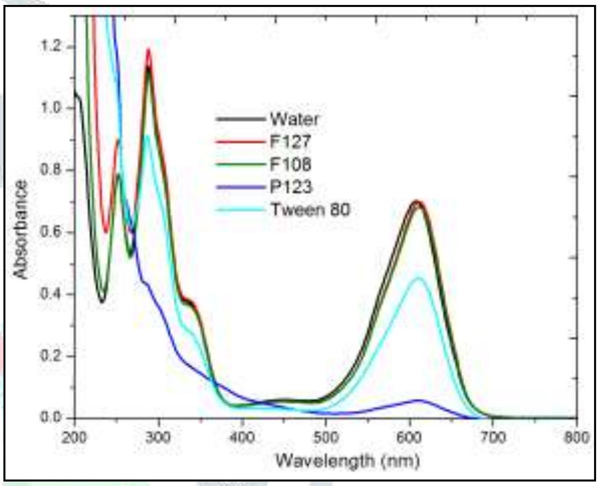
(A) Acid black-1



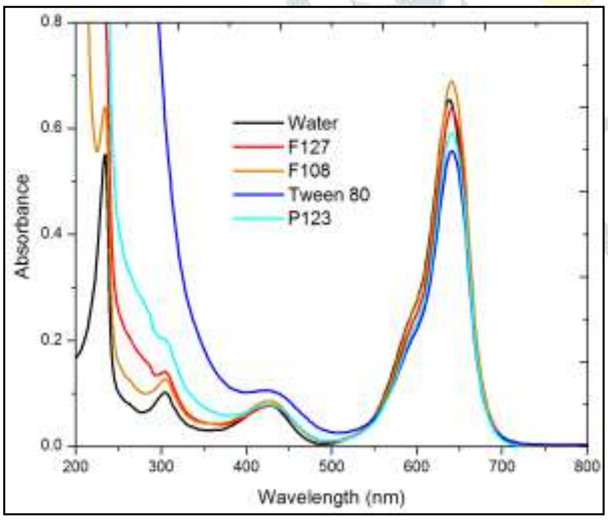
(B) Chloro phenol red



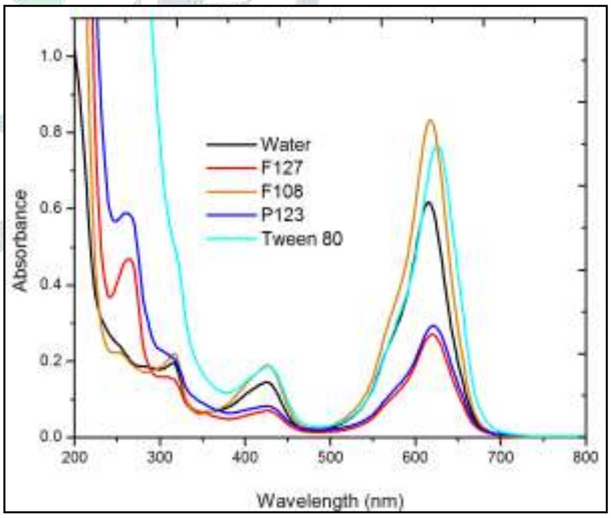
(C) Eosin yellow



(D) Indigocarmine



(E) Light green



(F) Malachite green

Figure 1. Visible absorption spectra of [A] Acid balack-1 (Ab-1), [B] Chloro phenol red (Cpr), [C] Eosin yellow (Ey), [D] Indigocarmine (Ic), [E] Light green (Lg) and [F] Malachite green (Mg) with four surfactants.

3.1.10. Naphthol blue black (Nbb)

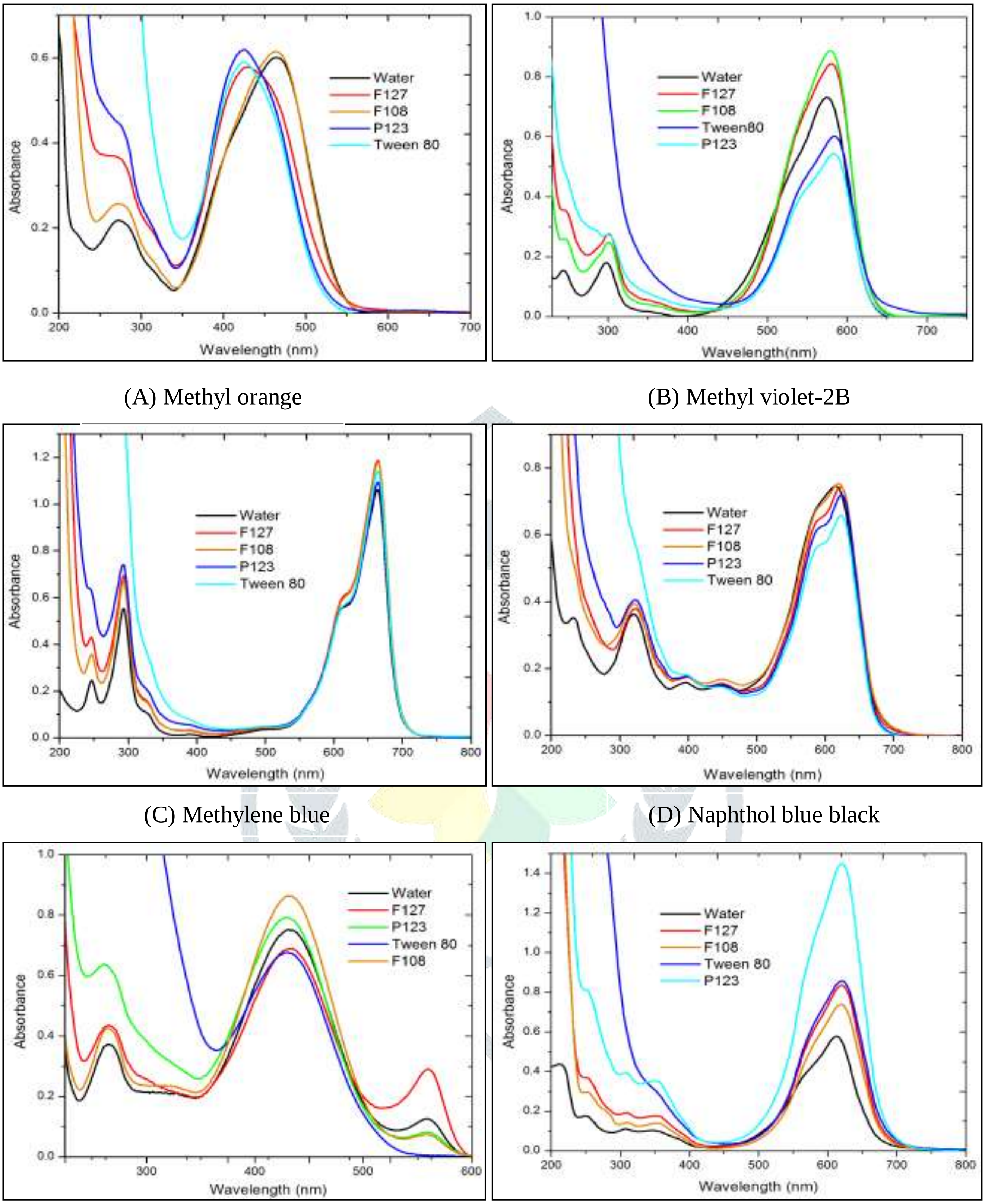
This anionic azo dye has molecular formula $C_{22}H_{14}N_6Na_2O_9S_2$. This is an acid dye showing two peaks in aqueous medium (319 and 614 nm) [46-47]. The high absorption band at 614 nm gets red shifted by 8, 6, 10, 9 nm with F127, F108, P123 and Tween 80 surfactant respectively. The change of pH was margical with all four surfactants. Wavelength absorbance had an increase for surfactant F108 and decrease for F127, P123 and Tween 80. This dye is acceptable for four surfactants to visualize spectral change.

3.1.11. Phenol red sodium salt (Prs)

The molecular formula is $C_{19}H_{13}NaO_5S$. It displays three bands at 264, 431 and 557 nm in aqueous solution [48-49]. The most prominent band was 431 nm which is used for discussion. On adding surfactants to the aqueous solution, wavelength got shifted by 2, 0, 0 and 4 nm respectively. The change in pH was negligible for F127, F108 and P123 surfactant, but Tween 80 had a change of pH from 6.39 to 4.98. This may be due to the change in the environment after addition of surfactant. The absorbance at wavelength was observed to increase for surfactant F108 and P123 and decrease for F127 and Tween 80. This dye on addition on surfactant F127 and P123 had a colour change from orange red to violet and orange red to yellow colour. There may be due to occurrence of oxidation reaction. Hence, this dye is not recommended for all four surfactants for UV absorbance studies.

3.1.12. Victoria blue- B (Vb-B)

This cationic dye has molecular formula $C_{33}H_{32}ClN_3$. It shows one prominent peak at 613 nm in aqueous medium [50-51]. After adding surfactants the wavelength was seen to have red shifted by 7, 6, 9 and 7 nm for F127, F108, P123 and Tween 80 respectively. The pH change was more for Tween 80 surfactant (6.95- 4.66) and small for F127, F108 and P123.The change in absorbance at wavelength was also seen to increase prominently. This dye is highly recommended for studying the spectral properties with all the above surfactants.



(A) Methyl orange (B) Methyl violet-2B

(C) Methylene blue (D) Naphthol blue black

(E) Phenol red sodium salt (F) Victoria blue-B

Figure 2. Visible absorption spectra of [A] Methyl orange (Mo), [B] Methyl violet-2B (Mv-2B), [C] Methylene blue (Mb), [D] Naphthol blue black (Nbb), [E] Phenol red sodium salt (Prs) and [F] Victoria blue-B (Vb-B)with four surfactants.

3.1.13. Reactive red-120 (Rr-120)

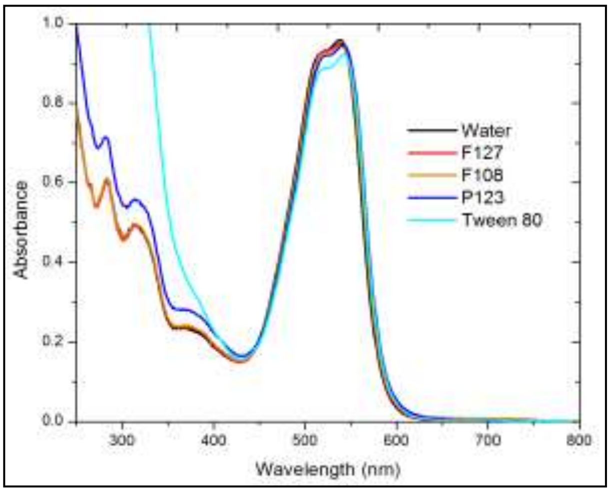
Molecular formula for the azo dye is $C_{44}H_{24}Cl_2N_{14}O_{20}S_6Na_6$ [19]. The dye showed wavelength at 538 nm in aqueous medium [52]. On addition of surfactants the maxima got red shifted by 4, 4 and 5 nm respectively for F108, P123 and Tween 80. There was no shifting for surfactant F127. This dye had the maximum change in pH for all the surfactants F127, F108, P123 and Tween 80 (6.71, 4.84, 4.91, 5.64 and 3.80 respectively). That means the addition of surfactant affected the environment of the dye to a great extent. However, the change in absorbance at wavelength was not very encouraging. Hence, this dye can be utilized for the studying the change in absorbance taking pH factor into consideration.

3.1.14. Reactive yellow- 84 (Ry-84)

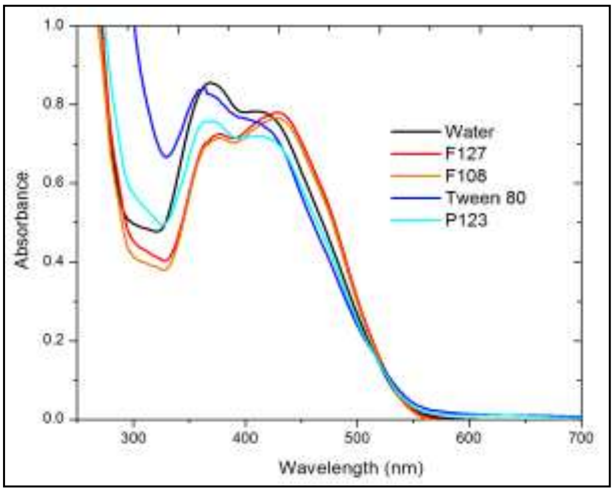
The anionic dye having molecular formula $C_{56}H_{38}Cl_2N_{14}Na_6O_{20}S_6$, has a red yellow colour [19, 53-54]. The aqueous solution displays a maxima at 376 nm. On adding surfactants there was no shift for F127 and F108; but 5 nm, 14 nm for P123 and Tween 80 respectively. The absorbance at wavelength was observed to increase for all four surfactants. The pH change was high for surfactant Tween 80 (5.83-3.93). pH is one of the most important factors controlling the adsorption of dyes in the dyeing process. The dye can be used for absorbance studies with surfactant P123 and Tween 80 but not for F127 and F108.

3.1.15. Trypan blue (Tb)

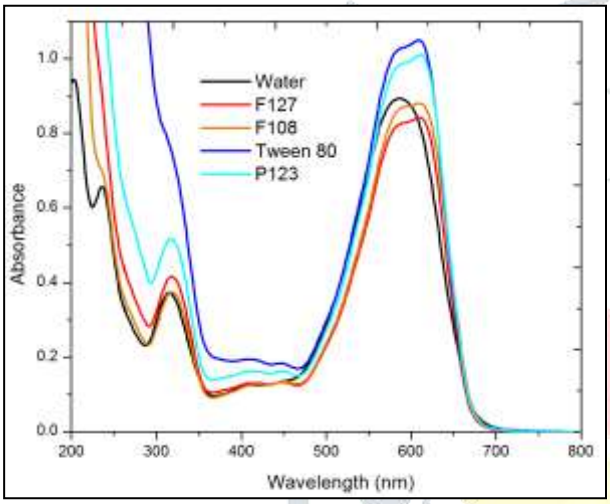
It has molecular formula $C_{34}H_{24}N_6Na_4O_{14}S_4$. It displays wavelength at 315 and 586 nm in aqueous medium [55-56]. The discussion here is confined to the latter peak. On addition of surfactant it got red shifted by 23, 23, 24 and 23 nm for F127, F108, P123 and Tween 80 respectively. There was only minimal change in pH on surfactant addition. The maximum absorbance got increased by addition of P123 and Tween 80 and decreased by F127 and F108 surfactants. This change in the absorbance value encourages using the dye for all four surfactant systems to study the dye-surfactant interaction.



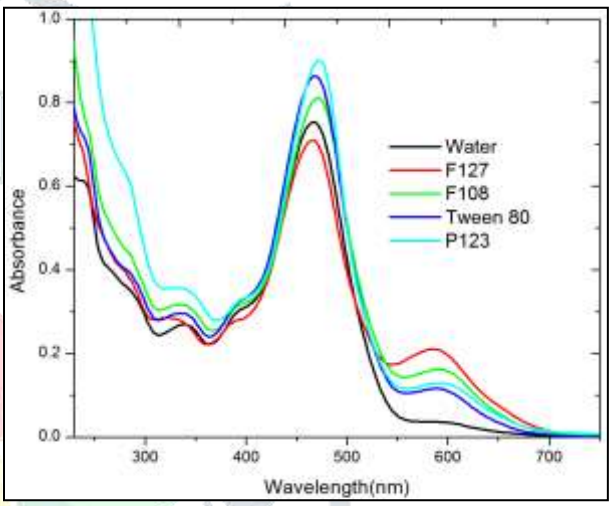
(A) Reactive red-120



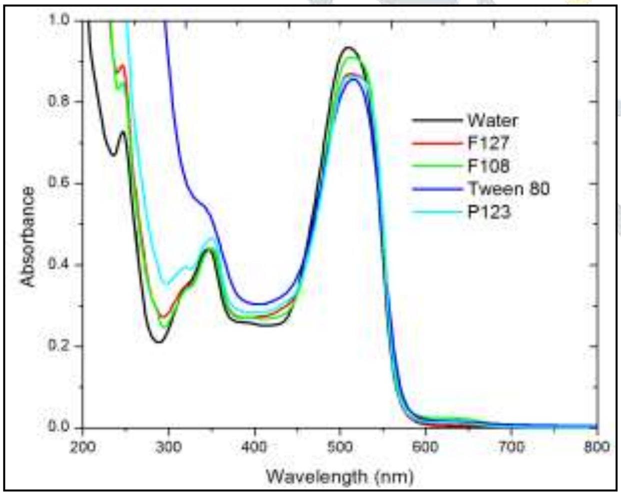
(B) Reactive yellow-84



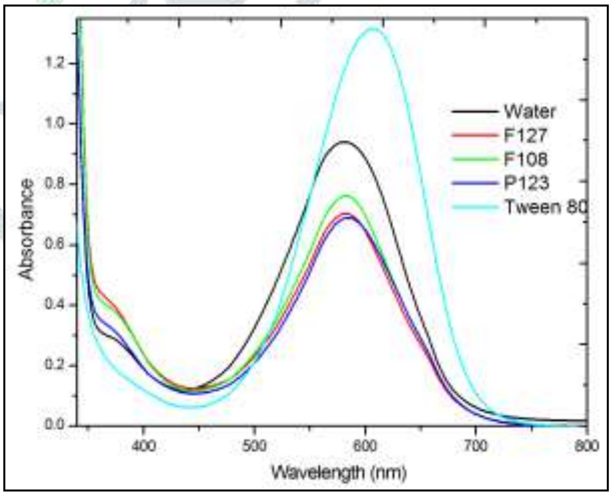
(C) Trypan blue



(D) Nitrazine yellow



(E) Brilliant crocein



(F) Methyl blue

Figure 3. Visible absorption spectra of [A] Reactive red-120 (Rr-120), [B] Reactive yellow-84 (Ry-84), [C] Trypan blue (Tb), [D] Nitrazine yellow (Ny), [E] Brilliant crocein (Bc) and [F] Methyl blue (Mlb) with four surfactants.

3.1.16. Nitrazine yellow (Ny)

This dye has molecular formula $C_{16}H_8N_4Na_2O_{11}S_2$. In aqueous medium the dye has a wavelength at 467 nm [57]. On addition of surfactant it shows blue shift by F127 and Tween 80 (1nm, 4 nm) and red shift by F108 and P123 (5 nm, 5 nm) respectively. The change in pH was not so conspicuous with all the four surfactants. The wavelength absorbance was observed to decrease for F127 and increase for F108, P123 and Tween 80. Only F108 and P123 are recommended to have good interaction with this dye.

3.1.17. Brilliant crocein (Bc)

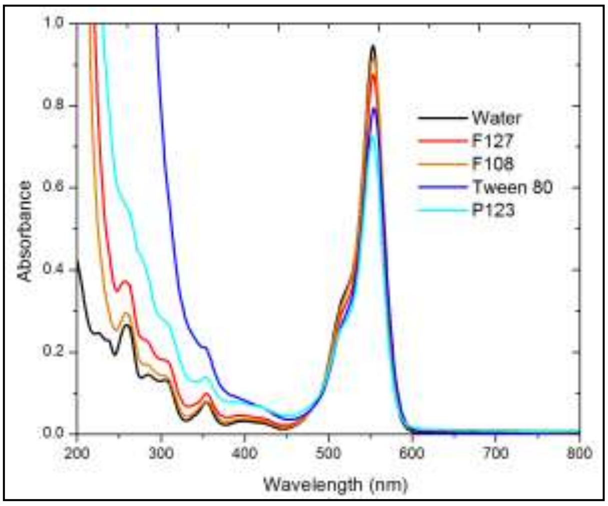
In water medium it displays wavelength at 509 nm [58-59]. The molecular formula for the dye is $C_{22}H_{14}N_4Na_2O_7S_2$. Adding surfactant, there appears a red shift by 3, 4, 5 and 2 nm for F127, F108, P123 and Tween 80. The peak absorbance was seen to decrease in all the four surfactants. For surfactant Tween 80 there was maximum change in pH (6.25 to 4.49). For other three the change in pH was not very significant. This dye may not be suitable to observe the spectral changes with the set of four surfactants.

3.1.18. Methyl blue (Mlb)

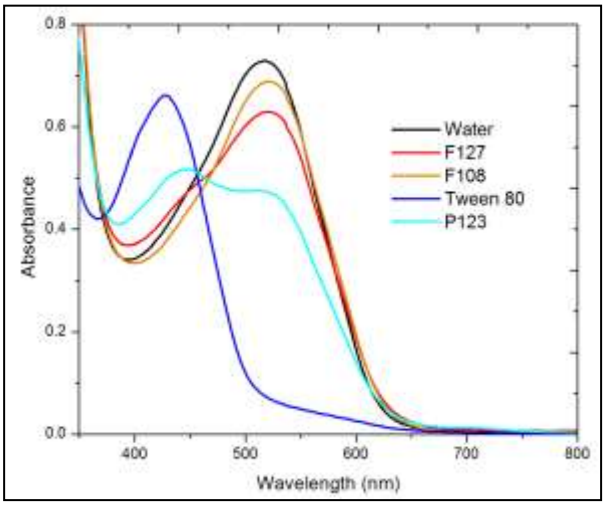
The molecular formula is $C_{37}H_{27}N_3Na_2O_9S_3$. In water methyl blue shows absorbance maxima at 581 nm [60-61]. On adding surfactants it was red shifted by 1, 2, 3 and 25 nm for F127, F108, P123 and Tween 80 respectively. There was decrease in wavelength absorbance for surfactants F127, F108, P123 and increase for Tween 80. For surfactant Tween 80 there was substantial change in pH (6.56-3.61). Out of four only surfactant Tween 80 is suitable to be used with this dye for observing spectral changes.

3.1.19. Rhodamine -B (Rh-B)

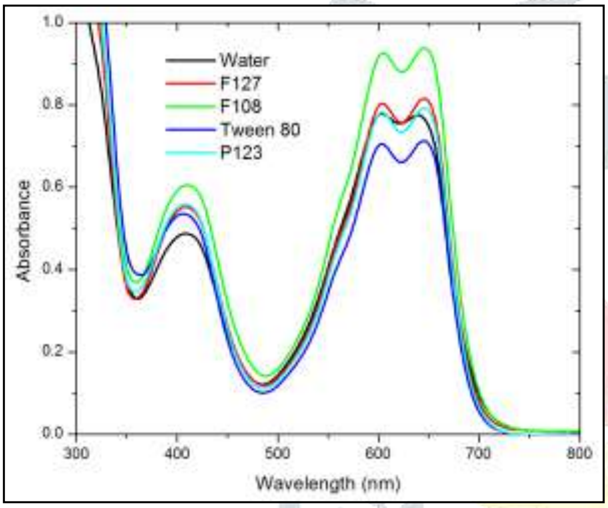
It has the molecular formula $C_{28}H_{31}ClN_2O_3$. When present in water it absorbs at wavelength 553 nm [62-64].On addition of surfactants it got red shifted for 1, 2 and 4 nm for F127, F108, Tween 80 and no shift for surfactant P123. The absorbance at wavelength was found to increase marginally for surfactant F108 and decrease for rest three surfactants. The pH change with P123 and Tween 80 was remarkable where as for F127 and F108 it was not so. Overall the results don’t indicate this dye and surfactants to be an ideal combination for studying the spectral properties.



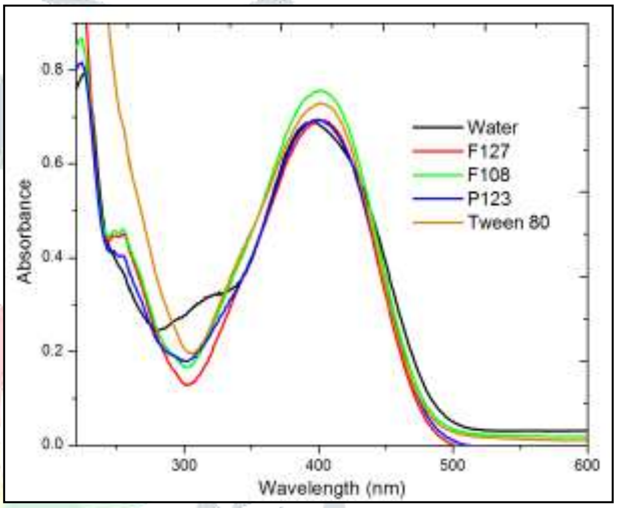
(A) Rhodamine-B



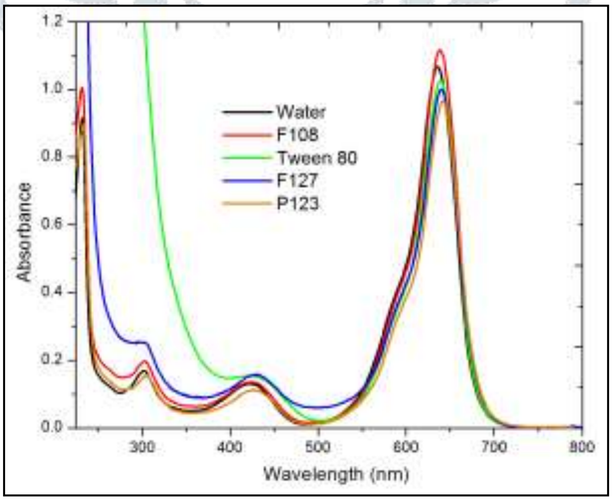
(B) Alizarin red-S



(C) Alizarin cyanine green



(D) Acid yellow-17



(E) Acid green-16

Figure 4. Visible absorption spectra of [A] Rhodamine-B (Rh-B), [B] Alizarin red-S (Ar-S), [C] Alizarin cyanine green (Acg), [D] Acid yellow-17 (Ay-17) and [E] Acid green-16 (Ag-16) with four surfactants.

Table 1 Values of absorbance and wavelength of Twelve dyes with four surfactants.

S.no	Name of dye	Water (No surfactant)		F127		F108		P123		Tween 80	
		Wave length (nm)	Absor bance	Wave length (nm)	Absor bance	Wave length (nm)	Absor bance	Wave length (nm)	Absor bance	Wave length (nm)	Absor bance
1	Acid black-1	615	0.764	620	0.752	622	0.750	623	0.828	623	0.796
2	Chloro phenol red	439	0.824	432	1.101	437	1.262	437	1.152	439	1.206
3	Eosin yellow	517	0.723	526	0.613	521	0.578	534	0.556	539	0.556
4	Indigo carmine	607	0.701	611	0.682	611	0.699	610	0.057	612	0.453
5	Light green	638	0.658	641	0.637	640	0.688	641	0.592	639	0.554
6	Malachite green	615	0.617	619	0.271	617	0.833	621	0.294	625	0.768
7	Methyl orange	463	0.584	428	0.557	462	0.587	425	0.619	424	0.596
8	Methyl violet-2B	575	0.731	580	0.844	579	0.887	583	0.543	584	0.601
9	Methylene blue	663	1.062	664	1.187	664	1.179	664	1.094	664	1.142
10	Naphthol blue black	614	0.746	622	0.745	620	0.754	624	0.719	623	0.657
11	Phenol red sodium salt	431	0.752	433	0.689	431	0.865	431	0.791	427	0.677
12	Victoria blue-B	613	0.578	620	0.835	619	0.738	621	1.448	620	0.856

Table 2 Values of absorbance and wavelength of Eleven dyes with four surfactants.

S.no	Name of dye	Water (No surfactant)		F127		F108		P123		Tween 80	
		Wave length (nm)	Absor bance	Wave length (nm)	Absor bance	Wave length (nm)	Absor bance	Wave length (nm)	Absor bance	Wave length (nm)	Absor bance
1	Reactive red-120	538	0.959	538	0.950	542	0.946	542	0.946	543	0.923
2	Reactive yellow-84	376	0.708	376	0.725	376	0.715	371	0.759	362	0.843
3	Trypan blue	586	0.884	609	0.862	609	0.854	610	1.011	609	1.051
4	Nitrazine yellow	467	0.753	466	0.710	472	0.811	472	0.902	470	0.879
5	Brilliant crocein	509	0.934	512	0.869	513	0.911	514	0.864	511	0.863
6	Methyl blue	581	0.941	582	0.703	583	0.762	584	0.689	606	1.317
7	Rhodamine –B	553	0.947	554	0.876	554	0.954	553	0.724	554	0.794
8	Alizarin red-S	516	0.729	521	0.630	520	0.689	509	0.475	427	0.662
9	Alizarin cyanine green	639	0.775	645	0.815	646	0.939	646	0.793	645	0.713
10	Acid yellow-17	396	0.689	401	0.694	403	0.757	399	0.695	401	0.730
11	Acid green-16	636	1.006	640	1.000	638	1.116	642	0.965	639	1.025

3.1.20. Alizarin red - S(Ar-S)

The empirical formula is $C_{14}H_7NaO_7S$. In water medium it displays two peaks at 335 and 516 nm [65-67]. We will discuss about the second peak because of more absorbance. After addition of surfactants F127 and F108 the peaks are seen to be red shifted by 5 and 4 nm and P123 and Tween 80; they are blue shifted by 7 and 89 nm respectively. Surfactant Tween 80 had the maximum change in pH (6.40 to 4.66). Other three pH were not much affected. But, the wavelength absorbance value was seen to be lowered for all four surfactants. This dye-surfactant combination can be suitable for observing the spectral changes, except surfactant F108.

3.1.21. Alizarin cyanine green (Acg)

The molecular formula is $C_{28}H_{20}N_2Na_2O_8S_2$. This is a cationic dye showing wavelength at 406 and 639 nm in aqueous medium. [68-69]. We have analysed the latter one here. There was red shift of wavelength by 6, 7, 7 and 6 nm for F127, F108, P123 and Tween 80. There was increase in absorbance at wavelength for F127, F108, P123 and decrease for Tween 80. This pH change was maximum for Tween 80. This can find suitability to study the dye-surfactant interaction from absorbance studies for all four surfactants.

3.1.22. Acid yellow - 17 (Ay-17)

This anionic acid dye has molecular formula $C_{16}H_{10}Cl_2N_4Na_2O_7S_2$. This dye displays spectra with absorption maxima at 396 nm in aqueous medium [15, 18, 70-71]. Surfactant addition red shifts the wavelength by 5, 7, 3 and 5 nm for F127, F108, P123 and Tween 80. The absorbance at wavelength is seen to increase in all the four cases. F127, F108 and P123 surfactant had minimal effect of pH on the dye but Tween 80 had substantial effects. This dye is suitable for surfactants F127, F108 and Tween 80 but not for P123.

Table 3 Shift of wavelength and change of pH of Twenty three dyes and four surfactants.

S.no	Name of dye	Water	F127		F108		P123		Tween 80	
		pH	Shift in wave length (nm)	pH	Shift in wave length (nm)	pH	Shift in wave length (nm)	pH	Shift in wave length (nm)	pH
1	Acidblack-1	6.85	5	6.11	7	6.22	8	6.15	8	4.56
2	Chloro phenol red	6.26	7	5.25	2	4.83	2	4.36	0	3.80
3	Eosin yellow	6.66	9	6.14	4	6.46	17	6.09	16	5.34
4	Indigocarmine	6.39	4	6.05	4	6.16	3	5.12	5	3.25
5	Light green	6.41	3	6.15	2	6.09	3	5.66	1	5.95
6	Malachite green	6.68	4	5.71	2	6.09	6	5.09	10	4.43
7	Methyl orange	6.63	35	6.20	0	6.56	38	6.05	39	4.09
8	Methyl violet-2B	5.71	5	4.00	4	3.92	8	5.81	9	4.16
9	Methylene blue	6.81	1	6.05	1	6.05	1	6.09	1	4.51
10	Naphthol blue black	6.26	8	6.42	6	6.16	10	5.70	9	5.96
11	Phenol red sodium salt	6.39	2	6.01	0	6.16	0	6.05	4	4.98
12	Victoria blue-B	6.95	7	6.15	6	6.61	9	6.34	7	4.66
13	Reactive red-120	6.71	0	4.84	4	4.91	4	5.64	5	3.80
14	Reactive yellow-84	5.83	0	5.74	0	5.68	5	5.36	14	3.93
15	Trypan blue	6.68	23	6.26	23	6.16	24	6.26	23	5.96
16	Nitrazine yellow	6.51	1	5.70	5	5.66	5	5.92	4	5.23
17	Brilliant crocein	6.25	3	6.02	4	6.49	5	5.83	2	4.49
18	Methyl blue	6.56	1	5.83	2	6.13	3	5.86	25	3.61
19	Rhodamine-B	6.84	1	6.03	1	6.32	0	5.98	1	4.53
20	Alizarin red-S	6.40	5	5.95	4	6.10	7	6.02	89	4.66
21	Alizarin cyanine green	6.11	6	6.15	7	6.40	7	6.11	6	4.67
22	Acid yellow-17	6.56	5	6.39	7	6.14	3	5.68	5	3.84
23	Acid green-16	5.93	4	5.79	2	5.82	6	5.64	3	3.86

3.1.23. Acid green - 16 (Ag-16)

This is an anionic acid dye with molecular formula $C_{58}H_{58}N_4Na_2O_{12}S_4$. It shows absorbance with wavelength at 636 nm and a small peak at 301 nm in aqueous medium [15, 72-73]. Upon addition of surfactants there was red shift by 4, 2, 6 and 3 nm for F127, F108, P123 and Tween 80 respectively. The wavelength absorbance value was almost constant. Hence, there was little effect. Only surfactant Tween 80 had some notable change in pH value where as F127, F108 and P123 displayed minimal change. This dye can be recommended for use with surfactant P123 and not for other three to observe dye-surfactant interaction.

4. CONCLUSION

Based on strong interaction causing noticeable change in the absorption spectra Ab-1, Ey, Nbb, Vb-B and Tb dyes are recommended for use with all the four surfactants viz. F127, F108, P123 and Tween 80. Five dyes are suggested for use with three surfactants each: Ey with F127, P123 and Tween 80; Mo with F127, P123 and Tween 80; Mv-2B with F127, P123 and Tween 80; Ar-S with F127, P123 and Tween 80; and Ay-17 with F127, F108 and Tween 80. Two dyes are found suitable with two surfactants each: Mg with P123 and Tween 80; Ny with F108 and P123; and Ry-84 with P123 and Tween 80. Additionally Cpr with F127, Ic with Tween 80, Rr-120 with Tween 80, Bc with P123, Mlb with Tween 80 and Ag-16 with P123 are recommended for ideal combinations. Total forty seven combinations are satisfactory out of ninety two. Maximum shift in absorption of 89 nm was observed in case of Ar-S and Tween 80 complex. No shift was noticed in seven dye-surfactant pairs viz. Cpr - Tween 80, Prs - F108, Prs - P123, Rr 120 - F127, Ry 84 - F127, Ry 84 - F108 and Rh B - P123. The use of these seven combinations for identifying spectral changes is discouraged.

Out of ninety two dye-surfactant combinations chosen it was observed that forty five have got shift below 5nm. Hence, dye-surfactant interaction in such cases may be weak and unsuitable for studying the spectral changes. On the other hand forty seven (52% of total) combinations had a shift above 5nm and hence considered suitable for the above study.

There were some minimal variations, either increase or decrease of pH in all the combinations on addition of surfactant to the dye. But in case of Tween 80 all the surfactants displayed substantial change in pH it fit for spectral studies from pH point of view. From the perspective of strong interaction through change in pH, use of Tween 80 with all the Twenty three dyes is recommended.

The above findings will help the researchers to successfully select dye-surfactant combinations.

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CONFLICT OF INTEREST

The authors declare that they have no competing financial interest.

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