Supplementary file

Halochromic effect/transitions and its role in the efficiency of chromotrope 2B based photo-galvanic cell

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1. Material and Method

KOH: Structural and Chemical Properties of KOH alkali involves, an ionic lattice composed of potassium cation and hydroxide anion.Solubility and thermodynamic behavior of KOH exhibits distinct solubility gradients across various media, like it is highly soluble in water, i.e., 121 g per 100 mL at 25 °C. The oxygen and hydrogen atoms are linked via covalent bond within hydroxide moiety **(Fig.S1).** The dissolution of KOH alkali in water is a strongly exothermic process, characterized by a significant release of enthalpy. Furthermore, the compound is intensely hygroscopic. Upon exposure to the atmosphere, it undergoes deliquescence, sequestering water vapor to transition from a solid state into a concentrated, viscous aqueous solution. Soluble in protic solvents such as glycerol and alcohols; however, it remains insoluble in non-polar or aprotic media like ether and liquid ammonia. It is utilized as a pH regulator and stabilizer, where its alkaline properties are leveraged to modulate acidity and maintain the structural integrity of food matrices.

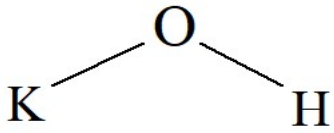

Figure S1 *Structure of potassium hydroxide alkali*

Sodium thiosulfate pentahydrate **:** The compound is a colourless and odourless solid exhibiting melting point of 48 °C and a boiling point of 100 °C. Further, high-grade specifications (99–100.5% assay via iodometric titration) ensure minimal contamination, with a maximum of 0.05% chloride, 0.2% total sulfite and sulfate, and 0.001% heavy metals (as lead). Structurally, the thiosulfate anion comprises a central sulfur atom in a distorted tetrahedral geometry, featuring a terminal one S=S bond, and different bonds of sulphur with three oxygen particles (i.e., two S-O bonds, one S=O bond) **(Fig.S2).** Sodium thiosulfate pentahydrate serves as a versatile reductant across various industrial and laboratory sectors. In textile processing, it is essential for the chemical reduction of dyes into their leuco forms-colorless, water-soluble intermediates, which allows for precise patterning and the efficient removal of residual pigments. Furthermore, its surfactant-like utility assists in the mechanical scouring of natural fibers such as wool, cotton, and silk to remove inorganic particulates like clay and sand.

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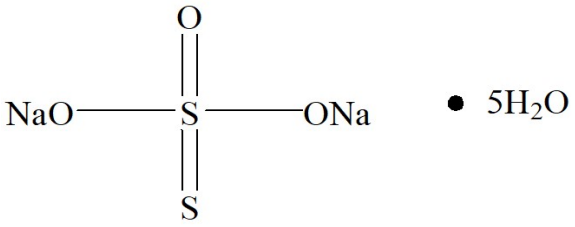

Figure S2 Structure of sodium thiosulphate pentahydrate reductant

Sulphamic acid surfactant: It is typically purchased with a high purity of at least 99.5% (determined by alkali metric assay). It has low levels of impurities, including a maximum of 0.05% sulfate (SO_4), 0.001% chloride (Cl^-), 0.002% nitrate (NO_3), 0.0005% heavy metals (as lead), 0.0005% iron (Fe), and 0.02% residue on ignition. Chemically, it exists as an intermediate between sulfuric acid and sulfamide, featuring a central sulfur atom bonded to an amino group, a hydroxyl group, and two oxygen atoms **(Fig.S3).** Sulfamic acid (H_3NSO_3) is a highly pure, white crystalline solid that serves as a stable and safer alternative to volatile liquid acids like hydrochloric acid. It is exceptionally effective as a descaling agent for removing mineral deposits and limescale. Beyond cleaning, it is widely utilized in the dye industry to stabilize pH levels and remove chemical by products like excess nitrites. Additionally, its unique properties as a surfactant allow it to improve foaming and maintain efficiency in hard water, making it a versatile tool for both industrial manufacturing and household maintenance.

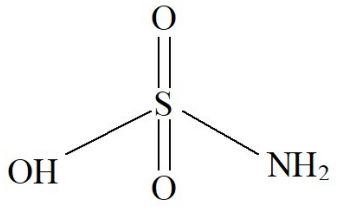

***Figure** S3 Structure of sulphamic acid surfactant*

Electrodes: To determine the working electrode area of 0.04 cm^2, piece of coin has been cut by measuring the dimension of 0.2 cm × 0.2 cm from the coin having 2.4 cm diameter. Therefore, it has area of 0.04 cm^2. Present research has not used whole coin as the working electrode, but, very small piece was cut from this coin. The measurement of this isolated small piece of coin (used as working electrode) is 0.2 cm × 0.2 cm (length and width). The rest of the coin has not been masked, because the whole coin has not been used as the working electrode. Instead, this dimension has been extracted from the original coin having 24 mm diameter, i.e., the piece of coin has been cut by measuring the dimension of 0.2 cm × 0.2 cm from coin having 2.4 cm diameter. Since, neither the whole coin (24 mm diameter) has been taken for experimentation, nor it has been masked, therefore, its whole surface area has not been considered for current density calculation.

(a) (b)

Figure S4 Fifty paisa coin used as working electrode.

Optimization of electrolyte concentrations for chromotrope 2B based photo-galvanic system:

Table S1 Optimized chemical composition of the chromotrope 2B based photo-galvanic system

Volume of the chemical used to prepare 40 ml electrolyte solution (in ml)					Resultant concentration			
KOH 1M	**Dye M/500**	**Reductant M/100**	**Surfactant M/10**	**Distilled water**	**KOH ×1M**	**Dye × 10^{-4} M**	**Reductan t× 10^{-4} M**	**Surfactant × 10^{-3}M**
8.0	0.2	0.8	1.0	30.0	0.20 M	0.1× 10^{-4}M	2.0×10^{-4}M	2.5×10^{-3}M

M, Moles per litre; ml, milli litre.

2. Spectra of pure chromotrope 2B dye solution

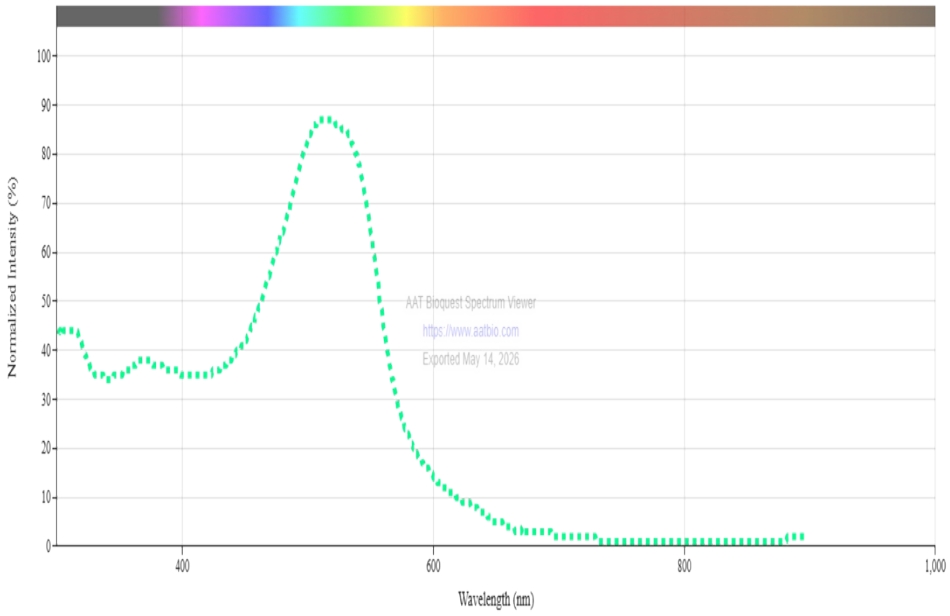

Figure S5 (a) *Spectra of pure chromotrope 2B dye solution (at pH ~7)* **[48]**

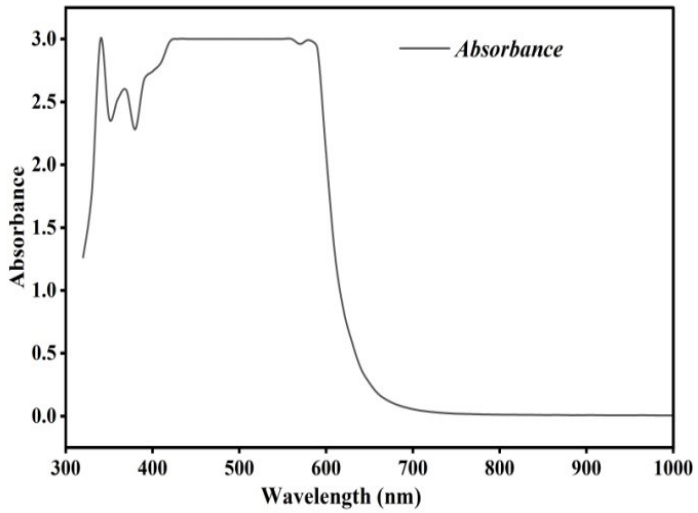

Figure S5 (b) *Spectra of pure chromotrope 2B dye solution (at pH ~7)*

3. Durability of Chromotrope 2B based photo-galvanic system

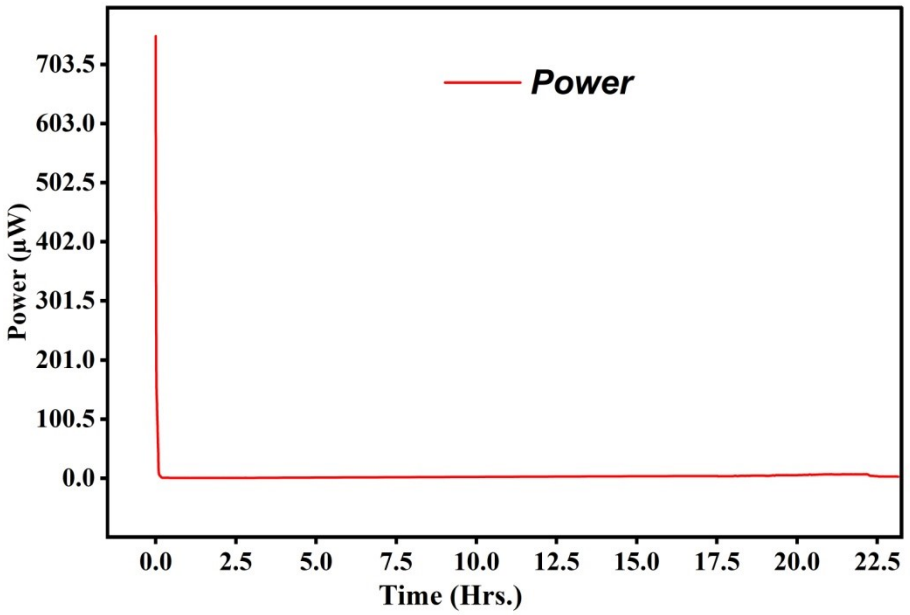

Figure S6 *Change in power with time during illumination*

Table S2 Long-term investigation of power (P_{pp}) during illumination in Chromotrope 2B dye sensitizer-Sodium thiosulphate pentahydrate reductant-Sulphamic acid surfactant-alloy based photo-galvanic system

Time (Hrs.)	Current (mA)	Potential (mV)	Power (μW)	Time (Hrs.)	Current (mA)	Potential (mV)	Power (μW)	Time (Hrs.)	Current (mA)	Potential (mV)	Power (μW)
Day 01											
0.00	2.96	254	751.84	0.75	0.14	1	0.14	1.70	0.11	1	0.11
0.02	3.76	47	176.72*	0.80	0.15	2	0.30	1.75	0.11	1	0.11
0.04	3.2	40	128.00	0.85	0.15	2	0.30	1.80	0.12	1	0.12
0.06	2.72	33	89.76	0.90	0.14	1	0.14	1.85	0.12	1	0.12
0.08	1.9	23	43.70	0.95	0.14	1	0.14	1.90	0.12	1	0.12

0.10	0.8	10	8.00	1.00	0.13	1	0.13	2.00	0.12	1	0.12
0.15	0.5	6	3.00	1.10	0.12	1	0.12	2.05	0.12	1	0.12
0.20	0.22	2	0.44	1.15	0.12	1	0.12	2.10	0.11	1	0.11
0.25	0.2	2	0.40	1.20	0.11	1	0.11	2.15	0.11	1	0.11
0.30	0.19	2	0.38	1.25	0.11	1	0.11	2.20	0.12	1	0.12
0.35	0.19	2	0.38	1.30	0.11	1	0.11	2.25	0.11	1	0.11
0.40	0.18	2	0.36	1.35	0.12	1	0.12	2.30	0.11	1	0.11
0.45	0.17	2	0.34	1.40	0.11	1	0.11	2.35	0.12	1	0.12
0.50	0.17	2	0.34	1.45	0.12	1	0.12	2.40	0.11	1	0.11
0.55	0.16	2	0.32	1.50	0.12	1	0.12	2.45	0.13	1	0.13
0.60	0.16	2	0.32	1.55	0.12	1	0.12	2.50	0.13	1	0.13
0.65	0.16	2	0.32	1.60	0.12	1	0.12	2.55	0.13	1	0.13
0.70	0.15	2	0.30	1.65	0.12	1	0.12	3.00	0.13	1	0.13
Day 02											
17.50	0.50	7.00	3.50	19.40	0.60	8.00	4.80	21.30	0.69	9.00	6.21
17.55	0.50	6.00	3.00	19.45	0.61	8.00	4.88	21.35	0.68	9.00	6.12
18.00	0.51	6.00	3.06	19.50	0.61	8.00	4.88	21.40	0.70	9.00	6.30
18.05	0.52	7.00	3.64	19.55	0.62	8.00	4.96	21.45	0.70	9.00	6.30
18.10	0.52	7.00	3.64	20.00	0.62	8.00	4.96	21.50	0.70	9.00	6.30
18.15	0.52	6.00	3.12	20.05	0.63	8.00	5.04	21.55	0.71	9.00	6.39
18.20	0.52	7.00	3.64	20.10	0.64	8.00	5.12	22.00	0.71	9.00	6.39
18.25	0.53	7.00	3.71	20.15	0.65	8.00	5.20	22.05	0.71	9.00	6.39
18.30	0.54	7.00	3.78	20.20	0.66	8.00	5.28	22.10	0.71	9.00	6.39
18.35	0.52	7.00	3.64	20.25	0.66	8.00	5.28	22.15	0.71	9.00	6.39
18.40	0.52	7.00	3.64	20.30	0.67	8.00	5.36	22.20	0.70	9.00	6.30
18.45	0.54	7.00	3.78	20.35	0.68	8.00	5.44	22.25	0.52	9.00	4.68
18.50	0.53	7.00	3.71	20.40	0.67	9.00	6.03	22.30	0.53	7.00	3.71
18.55	0.55	7.00	3.85	20.45	0.68	8.00	5.44	22.35	0.52	7.00	3.64
19.00	0.55	7.00	3.85	20.50	0.69	8.00	5.52	22.40	0.50	7.00	3.50
19.05	0.53	7.00	3.71	20.55	0.70	8.00	5.60	22.45	0.46	7.00	3.22
19.10	0.53	7.00	3.71	21.00	0.70	9.00	6.30	22.50	0.46	7.00	3.22
19.15	0.54	7.00	3.78	21.05	0.70	9.00	6.30	22.55	0.45	6.00	2.70
19.20	0.58	7.00	4.06	21.10	0.70	9.00	6.30	23.00	0.45	6.00	2.70
19.25	0.59	8.00	4.72	21.15	0.69	9.00	6.21	23.05	0.44	6.00	2.64
19.30	0.60	7.00	4.20	21.20	0.67	9.00	6.03	23.10	0.43	6.00	2.58
19.35	0.60	8.00	4.80	21.25	0.68	9.00	6.12	23.15	0.42	6.00	2.52

*Temperature, 25.2 ^{o}C; Humidity, 42 %; pH, 13.26; Conductance, 6830 µs/cm; V_{max}, 596 mV; V_{oc}, 594 mV;, illumination time (t_i), 45 mimutes; I_{max}, 7.30 mA; I_{SC}, 7.26 mA; I_{pp}, 3.18 mA; $V_{pp,}$ 379 mV; P_{pp}, 1205.22 µW; *$t_{1/2,}$ 176.72 (02 min.); [KOH], 0.20 × 1M; [Chromotrope 2B]; 0.1× 10^{-4}M; [Sulphamic acid],2.5×10^{-3}M; [Sodium thiosulphate pentahydrate], 2.0×10^{-4}M; distance of cell from illuminating source, 16 cm; Diffusion length (D_L) ,3.0 cm; Illumination intensity, 258 × 10 Lux (2.064 mWcm^{-2}); area of working electrode, 0.2 cm×0.2 cm*

Table S3 Comparative study of durability/performance of present chromotrope 2B based cells and other similar cells reported in literature

S.N.	Photo-galvanic system	$t_{1/2}$ (minutes)	Reference
1.	Brilliant Cresyl Blue + d Xylose + Sodium Lauryl Sulphate	**140**	**[59]**
2.	Sudan-I + Fructose + Sodium Lauryl Sulphate	**30**	**[60]**
3.	Allura Red + d-Galactose + Didecyl Dimethyl Ammonium Chloride	**28**	**[**61]
4.	Sunset Yellow + Ascorbic acid + Cetrimonium bromide surfactant	**07**	**[34]**
5.	Oil Red O + Sulphamic acid + Sodium thiosulphate pentahydrate	**45**	**[10]**
6.	Chromotrope 2B + Sulphamic acid + Sodium thiosulphate pentahydrate	**02**	**Present work**

4. **Change in potential with time for chromotrope 2B photo-sensitizer based photo-galvanic system**

Table S4 Change in potential with time for chromotrope 2B photo-sensitizer based photo-galvanic system

Time (min.)	00	05	10	15	20	25	30	35	40	45
Potential (mV)	122	135	738	618	640	666	671	692	712	738