



## **Polarographic and Voltammetric Investigation of Sudan I**

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### **Authors' contributions**

*This work was carried out in collaboration between all authors. Author YK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. She managed the analyses of the study and the literature searches. Authors MU and NM managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.*

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### **ABSTRACT**

The voltammetric and polarographic reduction of the 1-phenylazo-2-naphthol (Sudan I) on a hanging mercury drop electrode (HMDE) and static mercury drop electrode (SMDE) has been studied by using several techniques including square-wave voltammetry (SWV), differential pulse polarography (DPP), direct current polarography (DCP) and cyclic voltammetry (CV) in aqueous and ethanolic Britton-Robinson buffer media. The observed shift of the compound reduction peaks to more negative potentials with increasing pH indicates that hydrogen ions are involved in the electrode reaction. The effect of scan rate and pH on the reduction peaks has been studied. From the polarographic and voltammetric data, electrochemical reduction mechanism of the azo dye has been suggested. The reduction of the azo group to amino group in acidic, neutral and basic media was observed.

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## 1. INTRODUCTION

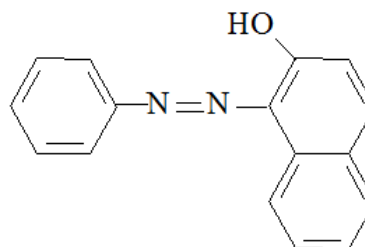
Sudan I (1-phenylazo-2-naphthol) is a synthetic lipid soluble azoic pigment. It has been widely used in chemical industries such as oils, fats, plastics, textiles, floor polishes and cosmetics [1]. Recently, Sudan I had been used extensively to give fascinating red colour to the products such as chilli sauce, ketchup, olive oil, the New Orleans baking chicken and many other frequently eaten foodstuffs. It has been confirmed that Sudan I is a potential carcinogen for humans [1]. In 1975, Sudan I was classified as Group 3 carcinogen by the International Agency for Research on Cancer [1-3]. For these reasons, Sudan I is strictly forbidden to be added to food products according to both the Food Standards Agency and European Union [1,2].

Many analytical methods such as high-performance liquid chromatography, gas chromatography-mass spectrometry, capillary electrophoresis, enzyme-linked immunosorbent assay, and electrochemical methods have been used for the determination of Sudan I [4-8]. But, many of them are time-consuming or involve a tedious extraction process before detection. In contrast, electrochemical techniques have some advantages such as rapid response, time saving, low cost, and high sensitivity [1,2,9-13]. To continue improving, the electrochemical characteristics of the reagents have been studied.

Electrochemical behaviour of important arylazo compounds was based on the dependence of the characteristic potential ie half-wave potential on electron density and other factors which in turn are simply co-related to physical and chemical property and activity. As a simple relationship has been found to exist between structure. Half-wave potential and reactivity, a better understanding of the effect of structure on the redox behaviour of these compounds can be obtained [14,15,16].

In the present work, the electrochemical behaviour of 1-phenylazo-2-naphthol was studied at a mercury electrode in B-R buffer electrolyte media by using SWV, DPP, DCP and CV techniques. At the same time, this study contributes to previous studies on the electrochemistry of other azo compounds. This compound has not been investigated at a mercury electrode by voltammetric methods up

to now. The molecular structure of the azo compound is given below (Scheme 1).



**Scheme 1. Molecular structure of the Sudan I**

## 2. EXPERIMENTAL

1-phenylazo-2-naphthol was purchased from Aldrich and used without further purification.  $10^{-3}$  M stock solution of the Sudan I dye was prepared in absolute ethanol. There is solubility problem of the compound in water media.  $10^{-4}$  M of Sudan I solution was prepared by appropriate dilution of the stock solution with absolute ethanol. Phosphoric acid, acetic acid, boric acid and sodium hydroxide were of purity p.a. 0.04 M Britton Robinson (B-R) buffer solution (pH:2.0-12.0) was used as supporting electrolyte and 10 mL of supporting electrolyte was established into a voltammetric cell. There is solubility problem of the compound in water media. 50% ethanol-water media in all solution was preferred due to the solubility problem in water. Then 800  $\mu$ L  $10^{-4}$  M of Sudan I solution was added with a micropipette into a voltammetric cell and then square wave and cyclic voltammograms were recorded. For DPP and DCP techniques measurements, 200  $\mu$ L  $10^{-3}$  M of Sudan I solution was added with a micropipette into a 10 mL 50% B-R(0.02M) buffer-50% ethanol supporting electrolyte in the voltammetric cell.

Polarographic and voltammetric experiments were carried out using a computer-controlled electroanalysis system (Metrohm 757 VA Computrace Electrochemical Analyser). A three-electrode combination system was used. This consisted of a Multi Mode Electrode (DME, SMDE and HMDE), an Ag/AgCl (saturated KCl) reference electrode and a Pt wire auxiliary electrode. All measurements were carried out at room temperature. Voltammetric parameters were selected for an equilibrium time of 5 s, a purge time of 300 s, and at a potential step of 4 mV, a pulse height of 50 mV and a scan rate ( $v$ )

of 200 mVs<sup>-1</sup>. The solutions were purged with purified clean dry nitrogen for five minutes prior to the experiments in order to remove dissolved oxygen from the media.

### 3. RESULTS AND DISCUSSION

The voltammograms of  $7.41 \times 10^{-6}$  M Sudan I in B-R (0.04 M) buffer and polarograms of  $1.96 \times 10^{-5}$  M Sudan I in 50% B-R (0.02 M) buffer-50% ethanol media at pH values between 2.0 and 12.0 have one reduction peak corresponding to the reduction of the azo group for SWV and DPP techniques respectively (Fig. 1). As shown in Fig. 1 peak currents and potentials are dependent on pH. Plots of peak potential ( $E_p$ ) versus pH of Sudan I are depicted in Fig. 2 for SWV and DPP techniques respectively. The observed shift of Sudan I reduction peaks to more negative potentials with increasing pH indicate that hydrogen ions are involved in the electrode reaction [17,18,19,14,20,21,22].

As shown in Fig. 2, peak potentials of the reduction peaks are a linear function of pH. The linear pH dependence of the peak potentials for SWV and DPP is given in Table 1. There is a linear relationship between the cathodic peak potential ( $E_p$ ) and pH value,  $E_p(\text{V}) = -0.0435 - 0.0663\text{pH}$  for SWV and  $E_p(\text{V}) = -0.0499 - 0.0699\text{pH}$  for DPP techniques respectively in aqueous and ethanolic Britton-Robinson buffer media (Table 1). The slopes -66,3 mV/pH and -69,9 mV/pH are very close to the theoretical value of -59 mV per unit pH required under the assumption of the  $2e^-/2H^+$  or  $4e^-/4H^+$  process of the electrochemical reduction of Sudan I [17].

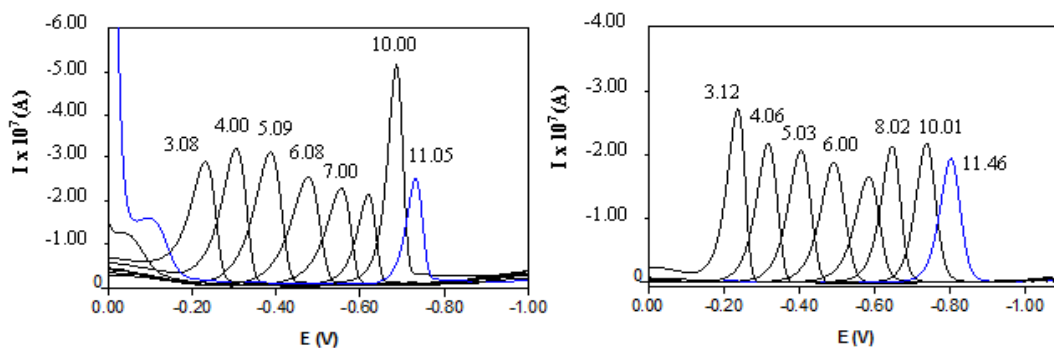
As shown in Fig. 3, SWV and DPP peak currents are different from each other depending on pH. Especially in SWV, peak currents firstly

decreased in the pH range of 5.0-8.5, and then increased in the pH range of 8.5-10.0. But in DPP technique, peak currents firstly decreased in the pH range of 2.7-6.5, and increased in the pH range of 7.0-8.5 and then decreased again in the pH range of 9.0-11.5.

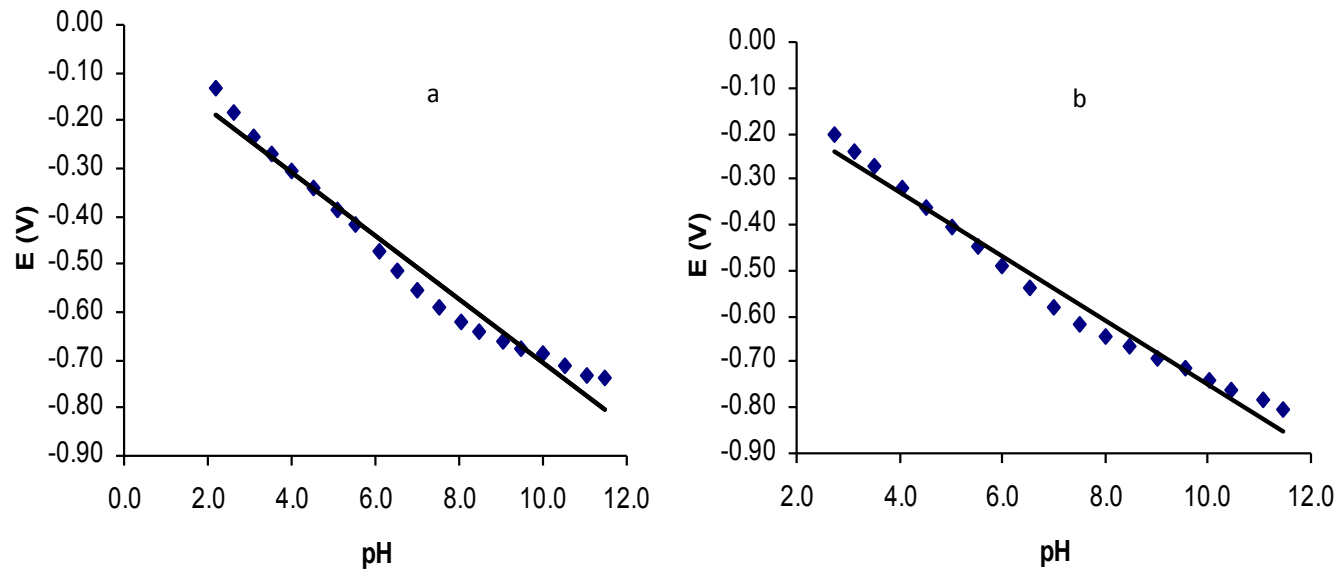
#### 3.1 DCP Studies

Fig. 4 shows typical DC polarograms of the azo compound in 50% B-R (0.02 M) buffer-50% ethanol medium, a well defined cathodic wave is seen in the pH range of 2.0-12.0 with a scan rate of 4 mV/s. Peak maxima were seen in the pH range of 2.0-12.0 at DC polarograms indicates that the adsorption of the azo compound on the electrode surface [22,23]. It can be said that similar electrode reactions occur in acidic and basic media, due to the approximately same wave heights are obtained in acidic and basic media [23,24].

Logarithmic analyses of the reduction waves calculated from the S-shaped DC polarograms in 50% B-R (0.02 M) buffer-50% ethanol buffer of different pH values (2.0–12.0) resulted in straight lines. Distorted polarographic waves have not been of concern for these logarithmic analyses. The  $\alpha_n$  values were calculated according to the Heyrovsky-Ilkovic equation [25-27]. Also, the  $E_p$ -pH plots for the reduction wave of Sudan I were straight lines of slopes (S) reported in Table 1. The number of hydrogen ions ( $\alpha_{H^+}$ ) participating in the rate-determining step was calculated using the slope values  $S_1$  ( $S_1 = -0.05916/\alpha_n$ ) and  $S_2$  ( $S_2 = -0.05916\alpha_n/\alpha_n$ ) of both the  $E$  versus  $\log(I/I_d - I)$  and  $E_{1/2}$ -pH plots, respectively. The effect of pH on the half wave potential ( $E_{1/2}$ ) of Sudan I and on the values involved in its reduction in 50% B-R (0.02 M) buffer-50% ethanol medium is



**Fig. 1. (a) Square wave voltammograms of  $7.41 \times 10^{-6}$  M Sudan I in B-R (0.04 M) buffer media (pH 3.08, 4.00, 5.09, 6.08, 7.00, 8.06, 10.00 and 11.05),  $\nu = 200$  mV/s, (b) Differential pulse polarograms of  $1.96 \times 10^{-5}$  M Sudan I in 50% B-R (0.02 M) buffer-50% ethanol media (pH 3.12, 4.06, 5.03, 6.00, 8.02, 10.01 and 11.46),  $\nu = 4$  mV/s**



**Fig. 2. Dependence of cathodic peak potentials as a function of pH for Sudan I a) SWV ( $7.41 \times 10^{-6}$  M), in B-R (0.04 M) buffer,  $v = 200$  mV/s, b) DPP ( $1.96 \times 10^{-5}$  M) in 50% B-R (0.02 M) buffer- 50% ethanol medium,  $v = 4$  mV/s**

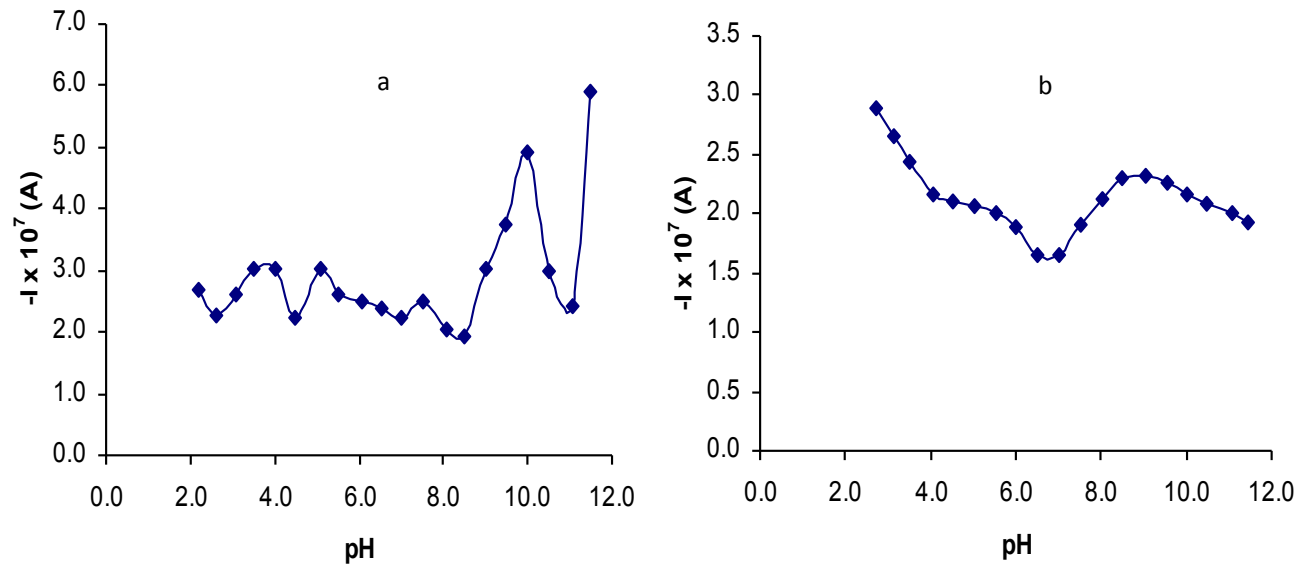


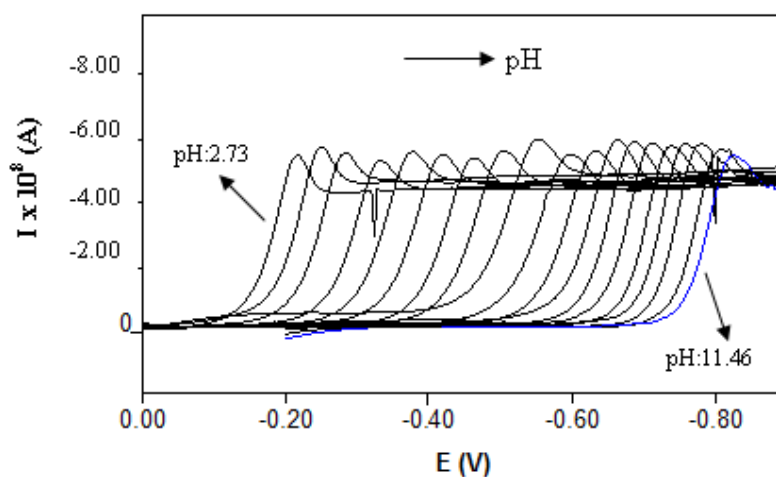
Fig. 3. Dependence of cathodic peak currents as a function of pH for Sudan I a) SWV ( $7.41 \times 10^{-6}$  M), in B-R (0.04 M) buffer,  $v = 200$  mV/s, b) DPP ( $1.96 \times 10^{-5}$  M) in 50% B-R (0.02 M) buffer- 50% ethanol medium,  $v = 4$  mV/s

shown in Fig. 5 and Fig. 6. The values and the number of hydrogen ions calculated indicate that the two protons and two electrons participate in the rate-determining step of the reactant centres. It is acceptable to assume that the Sudan I is reduced to corresponding amines at all studied pH values. The azo group is firstly reduced to

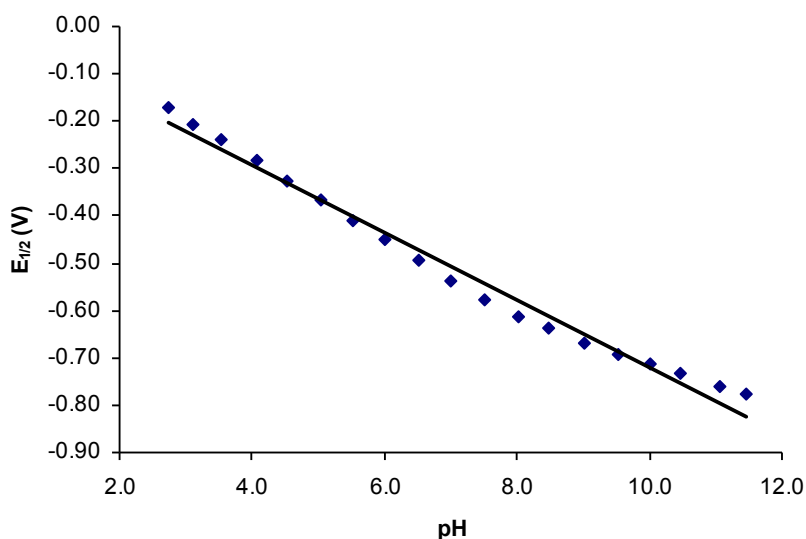
hydrazo form and then hydrazo form is reduced to yield the corresponding amines with a two electron, two proton processes in the rate determining step. In the second step, the azo group is reduced to aniline derivatives. The peak potentials of the two stage are approximately equal. (Scheme 2) [28,29,30,15,16].

**Table 1. Dependence of peak potentials on pH**

Medium	Peak equation	R <sup>2</sup>	Technique
B-R (0.04M) buffer	$E_p = -0.0435 - 0.0663\text{pH}$	0.9694	SWV
50% B-R (0.02 M) buffer -50% ethanol	$E_p = -0.0499 - 0.0699\text{pH}$	0.9775	DPP
B-R (0.04M) buffer	$E_p = -0.0605 - 0.0681\text{pH}$	0.9688	CV



**Fig. 4. Polarograms of  $1.96 \cdot 10^{-5}$  M Sudan I in 50% B-R (0.02 M) buffer-50% ethanol solution at pH 2.0-12.0, scan rate 4 mV/s, drop time 1 s, with SMDE and Ag/AgCl reference electrode**



**Fig. 5. The dependence of  $E_{1/2}$  values of Sudan I on pH in 50% B-R (0.02 M) buffer-50% ethanol medium,  $\nu = 4$  mV/s**

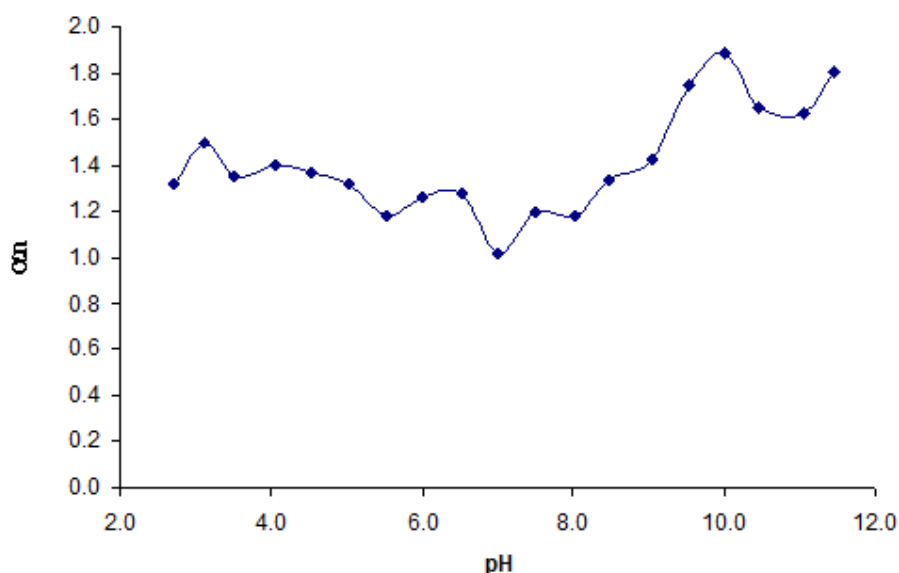


Fig. 6. The change of  $\alpha n$  with pH for the Sudan I in 50% B-R (0.02 M) buffer-50% ethanol medium

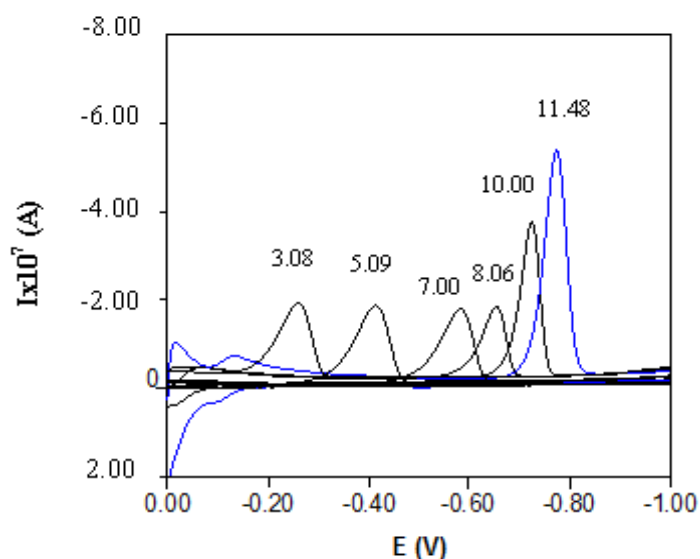


Fig. 7. CV voltammograms of  $7.41 \times 10^{-6}$  M Sudan I in B-R (0.04 M) buffer, (pH 3.08, 5.09, 7.00, 8.06, 10.00, and 11.48,  $\nu = 200$  mV/s)

### 3.4 CV Studies

CV voltammetric technique is required for explanation of the electrochemical behaviour of the compound [26]. In general, pH is one of the variables that commonly and vigorously affects the shapes of voltammograms, and therefore it is important to investigate the effects of pH on electrochemical systems. The pH dependence of the cyclic voltammograms of the azo compound

obtained in acidic, neutral and basic media is given in Fig. 7. The reduction of the azo group peak height is approximately constant in the pH range of 5.0-8.0 and increased in the pH range of 9.0-11.5. In the studied pH range (pH 2.0-12.0) cathodic process has been appeared to be an irreversible process as no anodic peak was observed in the reverse scan. The peak potentials ( $E_p$ ) shifted to more negative values upon the rise of each of the pH 2.0-12.0 which

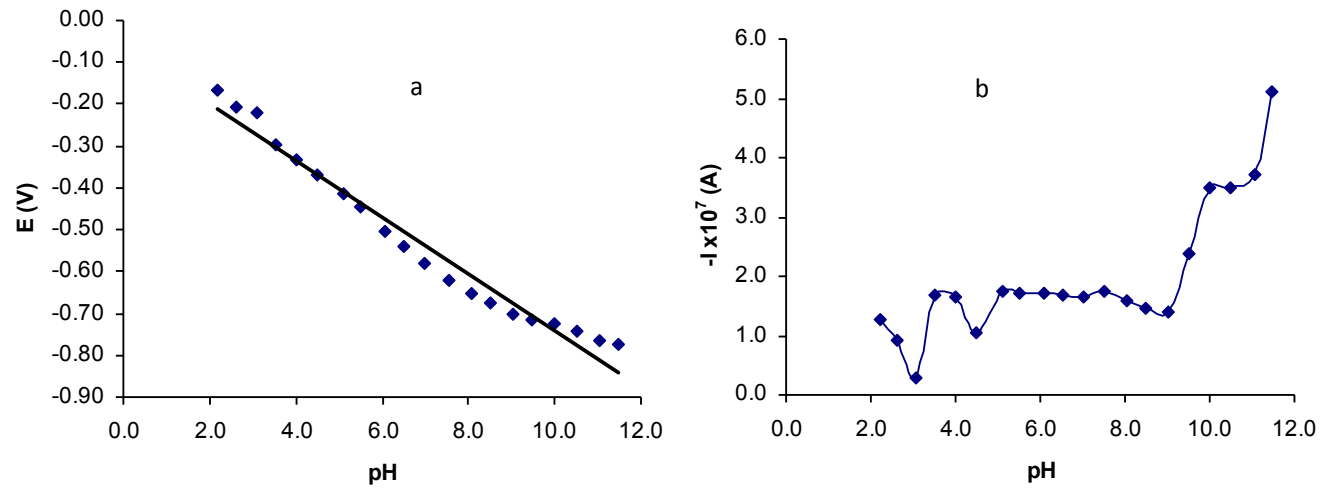
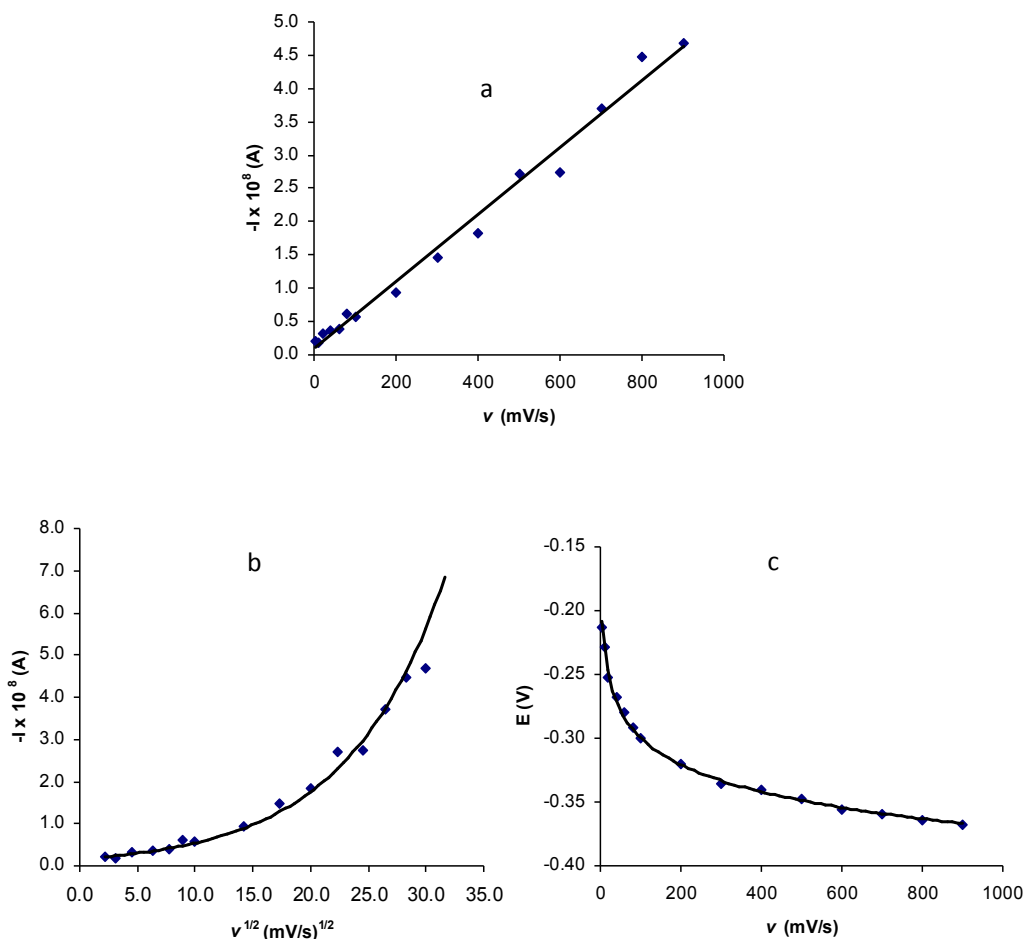


Fig. 8. Dependence of a) cathodic peak potentials and b) cathodic peak currents as a function of pH in B-R (0.04 M) buffer obtained for 7.41x10<sup>-6</sup> M solution of Sudan I for CV technique





**Fig. 9. a) The change of cathodic peak currents of  $9.90 \times 10^{-6}$  M Sudan I with scan rate at pH 4.15 in B-R (0.04 M) buffer b) The change of cathodic peak currents with square root of scan rate at pH 4.15, c) The change of cathodic peak potentials with scan rate at pH 4.15,  $v=5$ -1000 mV/s**

confirmed the involvement of protons in electrode reactions as SWV, DPP and DCP (Figs. 2 and 5) [17,18,19,14,20,21,22]. Fig. 8 shows a linear relationship between  $E_p$  and pH in the range of pH: 2.0-12.0 with a slope of  $-68.1$  mV/pH as can be seen in  $E_p = -0.0605 - 0.0681\text{pH}$  equation.  $-68.1$  mV/pH slope value indicates that the electrode reaction involves an equal number of electrons and protons for CV technique (Table 1) [21].

For the azo group, the dependence of the peak height for the reduction ( $I_p$ ) at a static mercury electrode (SMDE) on scan rate ( $v$ ) was examined in B-R (0.04 M) buffer at different pH values (pH 4.15, 7.06, 9.06 and 11.01). The peak currents change linearly with scan rate ( $v$ ) according to the equation  $I_p = Av^x$ . The  $x$  values 1.0 and 0.5

are expected for adsorption and diffusion controlled reaction, respectively. For Sudan I, the regression of  $\log(I_p)$  versus  $\log(v)$  gave a slope value of 0.672, 0.675, 0.841 and 0.611 for pH:4.15, pH:7.06, pH:9.06 and pH 11.06 respectively indicating that the reduction current had contributions from both diffusion and adsorption [1]. The  $I_p$  versus  $v^{1/2}$  relation is not linear (Fig. 9). With increasing scan rate  $I_p/v^{1/2}$  slope increases. This result proves that the complex electrochemical reaction of the azo compound occurs on the electrode surface [29, 31-35]. As scan rate was increased from 5 to 1000 mV/s, the cathodic peak potential shifted toward more negative values as expected for an irreversible reduction process (Fig. 9) [36-40].



- modified glassy carbon electrode. *Int J Electrochem Sci.* 2012;7:6331-42.
3. Gan T, Li K, Wu K. Multi-wall carbon nanotube-based electrochemical sensor for sensitive determination of Sudan I. *Sensor Actuat B-Chem.* 2008;132:134-39.
  4. He L, Su Y, Fang B, Shen X, Zeng Z, Liu Y. Determination of Sudan dye residues in eggs by liquid chromatography and gas chromatography-mass spectrometry. *Anal Chim Acta.* 2007;594:139-46.
  5. Ertas E, Ozer H, Alasalvar C. A rapid HPLC method for determination of Sudan dyes and Para Red in red chilli pepper. *Food Chem.* 2007;105:756-60.
  6. Zhang YP, Zhang YJ, Gong WJ, Gopalan AI, Lee KP. Rapid separation of Sudan dyes by reverse-phase high performance liquid chromatography through statistically designed experiments. *J Chromatogr A.* 2005;1098(1-2):183-7.
  7. Mejia E, Ding Y, Mora MF, Garcia CD. Determination of banned Sudan dyes in chili powder by capillary electrophoresis. *Food Chem.* 2007;102:1027-33.
  8. Combeau S, Chatelut M, Vittori O. Identification and simultaneous determination of Azorubin, Allura red and Ponceau 4r by differential pulse polarography: Application to soft drinks. *Talanta.* 2002;56:115-22.
  9. Gomez M, Arancibia V, Aliaga M, Nunez C, Romo CR. Determination of Sudan I in drinks containing Sunset yellow by adsorptive stripping voltammetry. *Food Chem.* 2016;212:807-13.
  10. Yang D, Zhu L, Jiang X. Electrochemical reaction mechanism and determination of Sudan I at a multi wall carbon nanotubes modified glassy carbon electrode. *J Electroanal Chem.* 2010;640:17-22.
  11. Lin H, Li G, Wu K. Electrochemical determination of Sudan I using montmorillonite calcium modified carbon paste electrode. *Food Chem.* 2008;107(1): 531-36.
  12. Wu M, Tang W, Gu J, Wang Q, He P, Fang Y. Electrochemical detection of Sudan I using a multi-walled carbon nanotube/chitosan composite modified glassy carbon electrode. *Am J Analyt Chem.* 2013;4:1-6.
  13. Chailapakul O, Wonsawat W, Siangproh W, Grudpan K, Zhao Y, Zhu Z. Analysis of sudan I, sudan II, sudan III, and sudan IV in food by HPLC with electrochemical detection: Comparison of glassy carbon electrode with carbon nanotube-ionic liquid gel modified electrode. *Food Chem.* 2008; 109:876-82.
  14. Karaman Y, Menek N. Investigation of electrochemical behaviour of 2-(5-Bromo-2-Pyridylazo)-5-[N-Propyl-N-(3-Sulfopropyl)Amino]Phenol disodium salt dihydrate. *J Electrochem Soc.* 2012; 159(10):H805-H10.
  15. Florence TM. Polarography of aromatic azo compounds. *Aust J Chem.* 1965;18: 609-18.
  16. Laitimer GW. Polarographic behaviour of metal chelates of o,o'-dihydroxyazo dyes. *Talanta.* 1968;15(1):1-14.
  17. Nigovic B, Simunic B, Hocevar S. Voltammetric measurements of aminosalicylate drugs using bismuth film electrode. *Electrochim Acta.* 2009;54(24):5678-83.
  18. Menek N, Basaran S, Karaman Y, Topcu S. Investigation of electrochemical behaviour of 3-Allyl-4-Hydroxy-3'-4'-Dimethylazobenzene. *Int. J. Electrochem. Sci.* 2013;8:6399-407.
  19. Karaman Y. Investigation of electrochemical behavior of Calmagite at a glassy carbon electrode Dyes Pigments. 2014; 106:39-44.
  20. Radi A, Mostafa MR, Hegazy TA, Elshafey RM. Electrochemical study of vinylsulphone azo dye Reactive Black 5 and its determination at a glassy carbon electrode. *J. Anal. Chem.* 2012;67(11):890-94.
  21. Radi AE, Nassef HM, El-Basiony A. Electrochemical behavior and analytical determination of Reactive Red 231 on glassy carbon electrode. *Dyes Pigments.* 2013;99:924-9.
  22. Jain R, Sharma N, Radhapyari K. Electrochemical treatment of pharmaceutical azo dye amaranth from waste water. *J Appl Electrochem.* 2009;39:577-82.
  23. Berek J, Fogg AG, Moreira JC, Zanoni MVB, Zima J. Polarographic and voltammetric determination of selected triazine-based azo dyes with different reactive groups. *Anal Chim Acta.* 1996; 320:31-42.
  24. Berek J, Ghosh A, Zima J. The polarographic and voltammetric determination of Semitypane Blue. *Collect Czech Chem Commun.* 1989;54:1538-48.
  25. Zuman P, Perrin CL. *Organic polarography.* New York. John Wiley & Sons. 1969;206.
  26. Meites L. *Polarographic techniques.* New York. John Wiley & Sons. 1965;727.

27. Bard AJ, Faulkner LR. Electrochemical methods. Canada. John Wiley and Sons Inc. 1980;718.
28. Menek N, Cakir O, Kocaokutgen H. Polarographic and voltammetric behaviour of 2-Hydroxy-3-Tert-Butyl-5-Methylazobenzene. Mikrochim Acta. 1996;122: 203-7.
29. Menek N. Polarographic and voltammetric behaviour of 2-hydroxy-3-methoxy-5-(2-propenyl)azobenzene. Anal Lett. 1998;31: 275-82.
30. Wang LH, Huang SJ. Studies on the voltammetric behavior of azo dyes and its determination in cosmetic products. Russ J Electrochem. 2010;46(12)1414-18.
31. Leitner MB, Ruhmann R, Springer J. Cyclovoltammetric studies of an azo anthraquinone system covalently bound to a polymer. Polym Avdan Technol. 1996; 7:437-41.
32. Dion D, Laviron E. The electrochemical reduction of thioisonicotinamide in an aqueous medium. Electrochim Acta. 1998; 43(14-15):2061-69.
33. Zanoni MVB, Carneiro PA, Furlan M, Duarte ES, Guaratini CCI, Fogg AG. Determination of the vinylsulphone azo dye, Remazol Brilliant Orange 3R, by cathodic stripping voltammetry. Anal Chim Acta. 1999;385:385-92.
34. Nigovic B, Komorsky-Lovric S, Simunic B. Electroanalytical studies of biologically active azosalicylic acid at a hanging mercury electrode. Electroanalysis. 2005; 17(10):839-45.
35. Chandra U, Gilbert O, Kumara Swamy BE, Bodke YD, Sherigara BS. Electrochemical studies of eriochrome black T at carbon paste electrode and immobilized by SDS surfactant: A cyclic voltammetric study. Int J Electrochem Sci. 2008;3:1044-54.
36. Ghoneim MM, El-Desoky HS Amer, SA, Rizk HF, Habazy AD. Electroreduction and spectrophotometric studies of some pyrazolylazo dyes derived from 3-Acetylamino-1-Phenyl-5-Pyrazolone in buffered solutions. Dyes Pigments. 2008; 77:493-501.
37. Yasin AS. Electrochemical studies and thermodynamic parameters of citrazinic acid azo dye and its nitro derivatives in DMF-aqueous solutions. Portugaliae Electrochim Acta. 2006;24:23-36.
38. Jain R, Varshney S, Sikarwar S. Removal of hazardous dye Reactofix Navy Blue 2 GFN from industrial effluents using electrochemical technique. Int J Environ Eng. 2009;1(1):95-105.
39. Jain R, Sharma N, Radhapyari K. Electrochemical treatment of pharmaceutical azo dye amaranth from waste water. J Appl Electrochem. 2009;39:577-82.
40. Maqbool H, Ganesh SD, Chandra U, Kumaraswamy BE, Pai VK. Cyclic voltammetric studies of synthesized cardanol based azo dyes. J. Chem. Sci. 2013;3(10):44-50.

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