

Synthesis of Arylhydrazonochromone as pH Sensors

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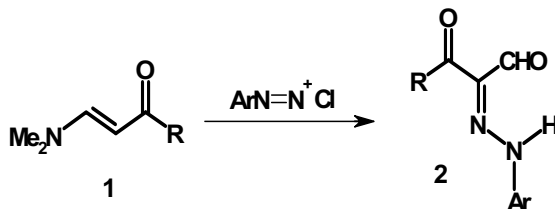
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Abstract. Coupling of the enaminone compound **3** with aryl diazonium salts affords the arylhydrazonochromones **6**. The latter showed a change in its colour upon changing the pH of the solution. The sensitivity of these molecules was clear in the pH range of 6-11. All four dyes start to show change in their visible spectra when the pH starts to reach the basic range.

Keywords: 2-Arylhyaazonopropanals, Arylhyaazonochromone, pH sensors.

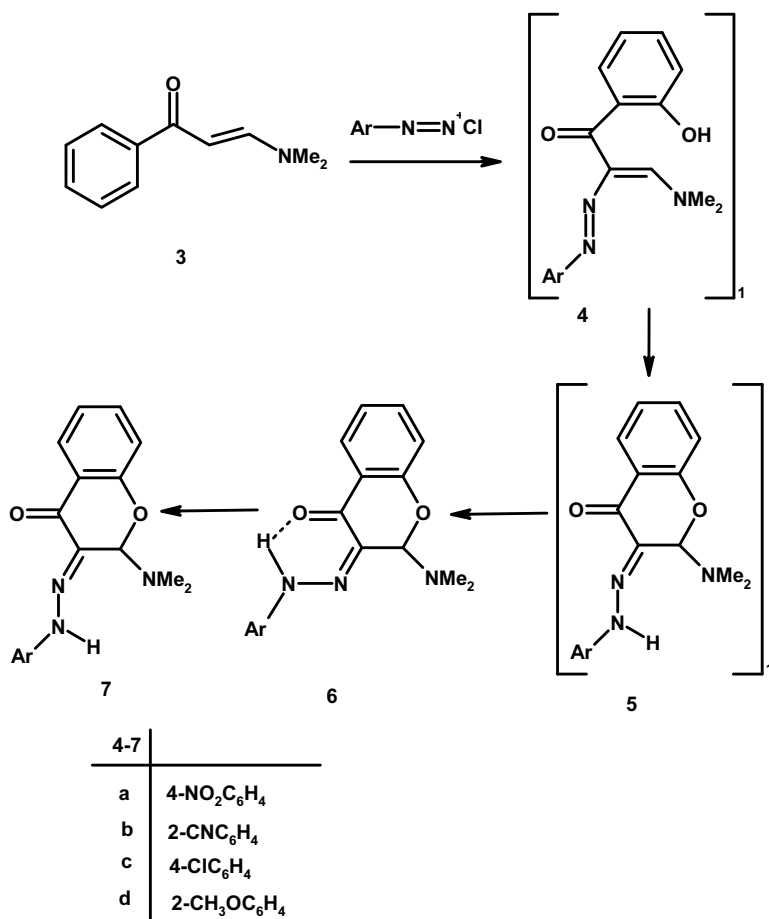
Introduction

Enaminones are versatile reagents and their chemistry is receiving now considerable attention^[1-5]. Some time ago, we reported that enaminones 1 couple with aromatic diazonium salts to yield 2-arylhyaazonopropanals^[6]. This reaction has been extensively utilized for synthesis of polyfunctionally substituted heteroaromatics by us^[7-12] and also other groups^[13].



Results and Discussion

In conjunction of this work, we have investigated the coupling reaction of 3 with aromatic diazonium salts with the aim of obtaining 4. The target molecules were not obtained instead cyclic N,O-acetals 6 were formed in good yields. We believe that the formed enazo compound 4 was initially cyclized into 5 that reacted with ethanol to yield the final isolable products 6^[14] (Scheme 1) (Table 2).



Scheme 1

¹³C and ¹H NMR spectra of the reaction products fit completely the proposed structure. Thus ¹³C NMR spectrum reveals two carbon signals at $\delta = 15.4$ and 64.4 ppm for the ether moiety. The sp³ carbon-2 appears at $\delta = 98.2$ ppm. The ¹H NMR spectrum shows the ether triplet and

quartet at $\delta = 1.0$ and 3.8 ppm and a singlet at $\delta = 5.9$ ppm for 2-H in the chromone ring. The D_2O -exchangeable signal at $\delta = 14.1$ ppm is attributed to a NH proton which is hydrogen-bonded to a carbonyl group. We considered it possible, however, that **7** exists in the enol azo form. To confirm with certainty the exact structure of **6a-c**.

Effect of PH on the Structure of Synthesized Dyes

The NMR spectra (DMSO- d_6) of all dyes presented here prove that these dyes exist as the hydrazo tautomer, as evidenced from the presence of imino proton at about 13 (ppm). Thus, it is anticipated that the effect of pH as well as the solvent polarity will correspondingly affect the spectral behavior of these dyes.

As shown in Fig. 1-4, it can be seen that alkaline pH has led to bathochromic shift if compared with acid one. This result can be explained as depicted in Fig. 13, in which it is indicated that as the pH increases, de-protonation occurs and the ionization of the dyes produces three possible resonance forms. Structure c will be the major contributor, oxygen being the most electronegative element and therefore more capable of supporting a negative charge. Since structure c is azo like form, therefore, it is expected that this form is the one which leads to bathochromic shift in comparison with the hydrazo tautomer which get stabilized in acidic pH.

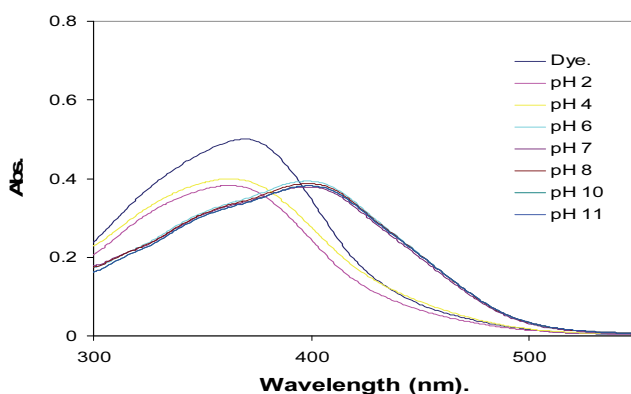
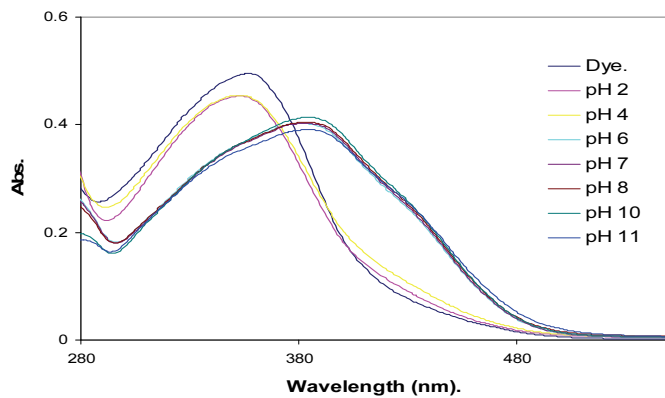
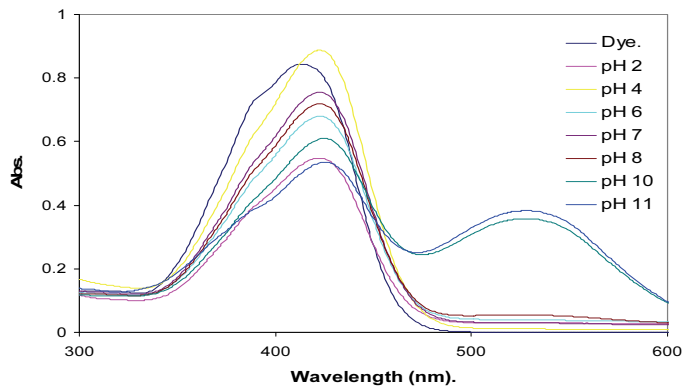
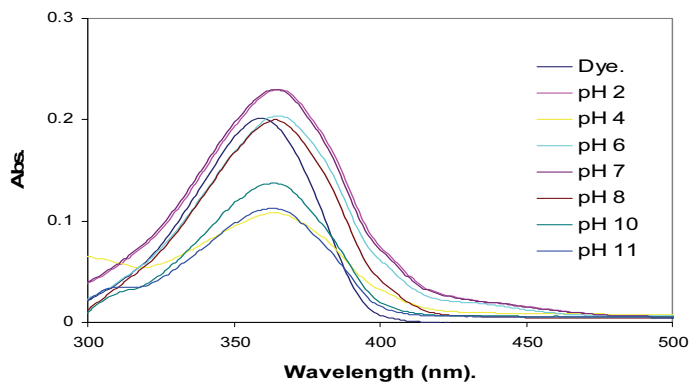
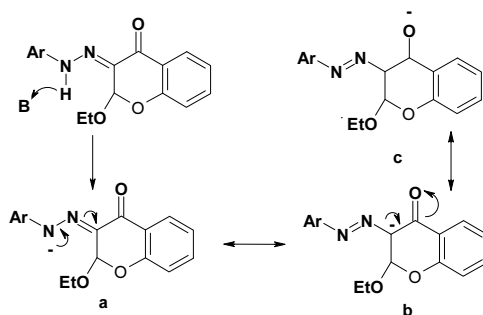


Fig. 1. Dye 1 in ethanol.

**Fig. 2. Dye 2 in ethanol.****Fig. 3. Dye 3 in ethanol.****Fig. 4 Dye 4 in ethanol.**

Solvent effect, however, although not clear but it seems that ethanol shows the best results if one would correlate them with the dye structure. The cycle on which the dyes showed repeatability on addition of base and acid are shown in Fig. 5.



Scheme 3. Ionization of hydrazone at increased pH and its resonance structures.

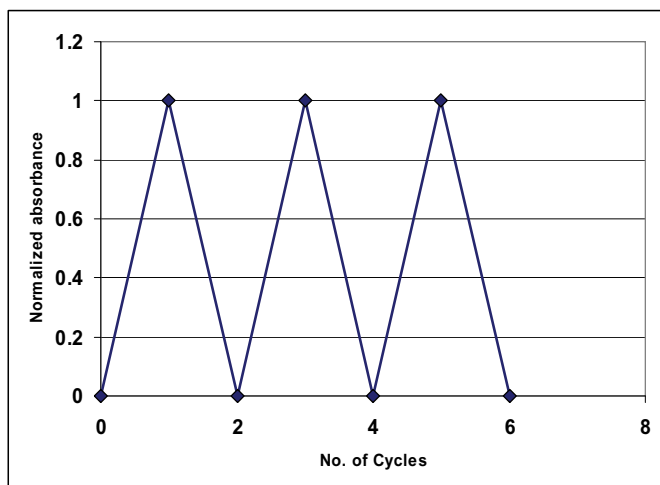


Fig. 5. Performance of dye 3 on successive addition of base and acid.

Experimental Section

General

All melting points were measured on a Gallenkamp Electrothermal melting point apparatus and are uncorrected. The IR absorption spectra were measured on a Nicolet Magna 520 FT IR Spectrophotometer. ^1H and ^{13}C NMR spectra were recorded in deuterated dimethylsulfoxide

[D6]-DMSO at 400 MHz on a Bruker DPX 400 MHz spectrometer using tetramethylsilane (TMS) as an internal reference; chemical shifts are expressed as δ values. Mass spectra were performed on a Shimadzu GCMS-QP 1000 Ex mass spectrometer at 70 eV. Elemental analyses were carried out at the Microanalytical Center at Cairo University. Electronic absorption measurements were made with a Shimadzu 1650 UV/Visible spectrophotometer in conjunction with a quartz cuvette of 1 cm path length. pH measurements of thiel buffer solutions were carried out using a Metler Toledo 230pH meter.

General Procedure for the Preparation of 6a-c^[5]

A cold solution of arenediazonium salt (0.1 mol) was prepared by adding a solution of sodium nitrite (1.5 g in 10 ml H₂O) to a cold solution of aryl amine (0.1 mol) in concentrated HCl (5 ml) with stirring as described earlier. The resulting solution of the arenediazonium salt was then added to a cold solution of enaminones 3 in EtOH (50 mL) containing sodium acetate (0.1 mol). The mixture was stirred at r.t. for 1 h and the solid product so formed was collected by filtration and crystallized from ethanol.

3-[(4-Chlorophenyl)Hydrazono]-2-Ethoxychroman-4-One (6a)

M.p. 120°C; orange crystals from ethanol; yield 90%. -IR ν = 3220(NH), 3080 (CH aromatic), 2946 (CH aliphatic), 1660 (C=O) and 1607 (C=N) cm⁻¹. -¹H-NMR (400 MHz, [D6]-DMSO): δ = 1.07 (t, 3H, CH₃CH₂), 5.95 (s, 1H, CH), 4.03 (q, 2H, CH₂CH₃), 7.18-7.52 (m, 8H, Ar-H) and 13.75 (s, 1H, NH). -¹³C-NMR (100 MHz, [D6]-DMSO): δ = 15.44 (CH₃CH₂O), 64.19 (CH₃CH₂O), 100.88 (CH), 117.44, 119.21, 122.46, 123.30, 127.14, 128.38, 129.1639, 129.88, 137.18, 141.69 (aromatic carbons), 156.48 (C=N-N), and 177.46 (C=O). -MS (EI, 70eV): m/z (%) = 330 (38.2) [M⁺]. - C₁₇H₁₅ClN₂O₃ (330.77): calcd. C 61.73; H 4.57, N 8.47; found: C 61.42; H 4.81, N 8.55.

3-[(2-Cyanophenyl)Hydrazono]-2-Ethoxy-Chroman-One (6b)

M.p. 154°C; Dark orange crystals from ethanol; yield 90 %. -IR ν = 3200 (NH), 3081 (CH aromatic), 2944 (CH aliphatic), 2221 (CN), 1651 (C=O) and 1605 (C=N) cm⁻¹. -¹H-NMR (400 MHz, [D6]-DMSO): δ = 1.10

(t, 3H, CH₃CH₂), 3.82 (q, 2H, CH₂CH₃), 5.98 (s, 1H, CH), 7.20-8.75 (m, 8H, Ar-H) and 14.10 (s, 1H, NH). -¹³C-NMR (100 MHz, [D₆]-DMSO): δ = 15.40 (CH₃CH₂O), 64.41 (CH₃CH₂O), 98.23 (CH), 116.18 (CN), 100.42, 119.37, 122.20, 123.54, 124.47, 127.52, 131.68, 133.68, 135.43, 137.919, 145.05, (aromatic carbons), 156.77 (C=N-N), and 178.62 (C=O). - MS (EI, 70eV): m/z (%) = 321 (26.9) [M⁺]. - C₁₈H₁₅N₃O₃ (321.33): calcd. C 67.28; H 4.71, N 13.08; found: C 67.12; H 4.80, N 13.15.

2-Ethoxy-3-[(4-Nitro-Phenyl)-Hydrazono]- chroman-One (6c)

M.p. 90°C; orange crystals from ethanol; yield 92%. -IR ν = 3200(NH), 3100 (CH aromatic), 2950 (CH aliphatic), 1665 (C=O) and 1607 (C=N) cm⁻¹. -¹H-NMR (400 MHz, [D₆]-DMSO): δ = 1.12 (t, 3H, CH₃CH₂), 5.99 (s, 1H, CH), 4.34 (q, 2H, CH₂CH₃), 7.21-8.27 (m, 8H, Ar-H) and 13.59 (brs, 1H, NH). - ¹³C-NMR (100 MHz, [D₆]-DMSO): δ = 15.43 (CH₃CH₂O), 64.40 (CH₃CH₂O), 100.81 (CH), 119.39, 122.33, 123.50, 126.14, 127.37, 131.79, 137.81, 143.15, 148.29 (aromatic carbons), 156.78 (C=N-N) and 178.0031 (C=O). - MS (EI, 70eV): m/z (%) = 341 (32.2) [M⁺]. -C₁₇H₁₅N₃O₅ (341.32): calcd. C 59.82; H 4.43, N 12.31; found: C, 60.01; H 4.58, N 12.11.

Electronic Absorption Measurements

Preparation of Solutions

A stock 1×10^{-4} M solution of dyes (1-4) was prepared by dissolving an appropriate weight of the dye in minimum amount (10 ml) of pure acetone, ethanol and methanol and brought to 50 ml in a calibrated flask with acetone, ethanol and methanol (Table 1-3).

Thiel buffer solutions of pH values 2-11 (boric acid, disodium tetraborate, succinic acid, sodium sulphate and sodium bicarbonate) were prepared by the recommended method (1).

One ml of solution of dyes (1-4) was transferred to 10 ml calibrated flask then 5 ml of buffer solution was added then completed with (acetone or ethanol or methanol) to the mark and the new concentration of dye was 1×10^{-5} M. After that the absorption spectra of dyes in different pH's were carried out.

Table 1. Absorbance maxima of dyes (1-4) in acetone solution of different pHs.

Dyes		Absorbance maxima in acetone	pH						
			2	4	6	7	8	10	11
1	λ_{\max}	369.5	369.5	369.5	401	400.5	404	404.5	402
	Abs.	0.645	0.663	0.667	0.640	0.572	0.671	0.651	0.494
	$\Delta\lambda$		0	0	-31.5	-31	-34.5	-35	-32.5
2	λ_{\max}	356.5	359.5	359	388	391	391.5	392.5	392.5
	Abs.	0.674	0.674	0.650	0.591	0.586	0.602	0.582	0.539
	$\Delta\lambda$		-3	-2.5	-31.5	-34.5	-35	-36	-36
3	λ_{\max}	415	422	421	422.5	422.5	423	423	424
	Abs.	0.666	0.711	0.728	0.685	0.684	0.451	0.440	0.377
	$\Delta\lambda$		-7	-6	-7.5	-7.5	-8	-8	-9
4	λ_{\max}	357	362.5	364	364	364.5	364	364	364
	Abs.	0.337	0.435	0.311	0.266	0.274	0.266	0.262	0.261
	$\Delta\lambda$		-5.5	-7	-7	-7.5	-7	-7	-7

$$\Delta\lambda = \lambda_{\max \text{ acetone}} - \lambda_{\max \text{ pH}}$$

Table 2. Absorbance maxima of dyes (1-4) in ethanol solution of different pHs.

Dyes		Absorbance maxima in ethanol	pH						
			2	4	6	7	8	10	11
1	λ_{\max}	374.5	372	371.5	357.5	363.5	363.5	363.5	364.5
	Abs.	0.696	0.679	0.703	0.688	0.546	0.564	0.557	0.535
	$\Delta\lambda$		2.5	3	17	11	11	11	10
2	λ_{\max}	360	357.5	358	354.5	353.5	353.5	354.5	354.5
	Abs.	0.415	0.389	0.377	0.283	0.277	0.280	0.274	0.269
	$\Delta\lambda$		2.5	2	5.5	6.5	6.5	5.5	5.5
3	λ_{\max}	412	422.5	422.5	423	423	423	425	425
	Abs.	0.560	0.548	0.887	0.681	0.756	0.720	0.610	0.536
	$\Delta\lambda$		-10.5	-10.5	-11	-11	-11	-13	-13
4	λ_{\max}	358.5	363.5	363	364.5	363.5	363.5	363	363
	Abs.	0.221	0.230	0.108	0.204	0.230	0.200	0.138	0.113
	$\Delta\lambda$		-2	-4.5	-6.5	-5	-5	4.5	-4.5

$$\Delta\lambda = \lambda_{\max \text{ ethanol}} - \lambda_{\max \text{ pH}}$$

Table 3. Absorbance maxima of dyes (1-4) in methanol solution of different pHs.

Dyes		Absorbance maxima in methanol	pH						
			2	4	6	7	8	10	11
1	λ_{\max}	369	362.5	363	397	397	398	399	400.5
	Abs.	0.500	0.383	0.400	0.394	0.379	0.387	0.382	0.385
	$\Delta\lambda$		6.5	6	-28	-28	-29	-30	-31.5
2	λ_{\max}	356.5	352.5	352	380.5	384	384	384.5	384
	Abs.	0.495	0.453	0.454	0.402	0.403	0.405	0.414	0.391
	$\Delta\lambda$		4	4.5	-24	-27.5	-27.5	-28	-27.5
3	λ_{\max}	412.5	423	423	423	423	423.5	423.5	423.5
	Abs.	0.341	0.443	0.451	0.445	0.440	0.439	0.421	0.377
	$\Delta\lambda$		-10.5	-10.5	-10.5	-10.5	-11	-11	-11
4	λ_{\max}	359	368.5	369	370.5	368.5	368.5	364	363
	Abs.	0.183	0.239	0.183	0.180	0.178	0.173	0.183	0.182
	$\Delta\lambda$		-9.5	-10	-11.5	-9.5	-9.5	-5	-4

$$\Delta\lambda = \lambda_{\max \text{ methanol}} - \lambda_{\max \text{ pH}}$$

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تحضير بعض مشتقات أرايل هيدرازونو كرومون كمحسسات لتغير الرقم الهيدروجيني

خيرية الأحمري ، و خديجة الزايدي، و ^١عبدالله عسيري

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المملكة العربية السعودية

المستخلص. تزاوج مركب الإينامينون ٣ مع أملاح الديازونيم أعطى مركب الأرايل هيدرازونو كرومون رقم ٦. وبين المركب الآخر تغيراً في اللون نتيجة تغيير الرقم الهيدروجيني للمحلول. وقد ظهرت حساسية هذه المركبات للرقم الهيدروجيني بشكل واضح في المدى من ٦- ١١. وأظهرت محاليل هذه المركبات تغيراً في اللون عند بدء المحلول بالوصول إلى المدى القاعدي.