Aromatic Enaminones. Part 1. Ultraviolet Absorption of *N*-Aryl Enaminones derived from Dimedone

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A series of enaminones derived from dimedone and various substituted anilines has been prepared. Their u.v. spectra are reported for acidic, neutral, and alkaline aqueous solution. For *m*-substituted derivatives the spectra show bathochromic shifts in comparison with aliphatic enaminones. These shifts are lower for *o*-substituted compounds because of steric interactions, and for *p*-substituted derivatives they vary with the properties of the substituent. Overall the aromatic ring is an electron donor to the enaminone system. Most of the compounds show hypsochromic shifts due to *O*-protonation; two (which have *p*-nitro-groups) show acidic properties in alkaline solution.

In continuation of studies [1] of the physical and chemical properties of enaminones, we have prepared and characterized some typical *N*-aryl enaminones. The compounds studied are listed in Table 1 together with their u.v. data. A number of aliphatic enaminones are included for comparison.

Most of the compounds reported were prepared by refluxing dimedone and the appropriate base in an aromatic solvent, with removal of the water produced by azeotropic distillation. The phenylenediamine compounds (22)—(24) reacted satisfactorily in this way provided that a 1 : 1 molar ratio of reactants was used; there were then no significant amounts of products from two molecules of dimedone and one of phenylenediamine. However, the derivative of *m*-phenylenediamine (23) prepared in this way was difficult to purify and was better prepared by catalytic hydrogenation of the *m*-nitro-compound (26). Although *m*-nitroaniline reacted normally with dimedone, the *o*- and *p*-nitroanilines did not, but they did react with the *O*-methyl derivative of dimedone [2] in the presence of boron trifluoride. This technique was also used to prepare the derivative of 3,5-dinitroaniline (28).

U.v. spectra were determined for some of the compounds in acid and alkali at various concentrations. Compounds (1), (3), (5), (7), (8), (15), (18), (19), and (22)—(26) were examined in various concentrations of acid. They showed hypsochromic shifts on moving from neutral to acidic solution, but these were complete in 0.1M-hydrochloric acid. Solutions in M- and 10M-hydrochloric acid showed no further shifts. In 0.001M-acid no shifts were apparent and in 0.01M-acid they were usually incomplete. Generally there is no significant change in u.v. absorption in passing from neutral to alkaline solution, but for compounds (16) and (18), where changes were seen, spectra in M-sodium hydroxide were identical with those in 0.1M-alkali. For these reasons u.v. data for solutions in 0.1M-hydrochloric acid and 0.1M-sodium hydroxide are presented as well as those for neutral solutions.

Enaminones are known to undergo protonation on oxygen.[3] Some of the early evidence for this depended upon the u.v. absorption of solutions of enaminone salts.[4] The low pK_a values reported [5] emphasise the importance of using a high concentration of acid if spectra of fully protonated enaminone molecules are to be seen.

The primary (1), secondary (2), and tertiary [(3)—(6)] aliphatic enaminones in Table 1 show u.v. maxima in water at increasing wavelengths as the number of alkyl groups increases. This is as expected from the electron-donating inductive effects of the alkyl groups. These compounds show hypsochromic shifts of 11—18 nm in 0.1M-hydrochloric acid due to the *O*-protonated species.

The secondary aromatic enaminone (7) derived from aniline has $\lambda_{max.}$ 309 nm in water. This is a value higher than any observed for even a tertiary aliphatic enaminone, and must mean that the benzene ring is an electron donor to the enaminone system. In this respect one aromatic ring is more effective than two aliphatic groups. This is also true for aromatic rings containing *m*-substituents [*e.g.* (9)]. Even compounds with *m*-substituents which have electron-withdrawing inductive effects [(14), (17), (20), (23), and (26)] show maxima at slightly longer wavelengths in water than the unsubstituted compound (7).

The effect of protonation in these *m*-substituted compounds and in the unsubstituted compound (7) is to cause a 10—13 nm hypsochromic shift [except for compound (23) which shows a shift of 7 nm; see later]. This is similar to the shifts of the aliphatic enaminones (2)—(6) and means that these aromatic enaminones also undergo protonation on the carbonyl oxygen atom.

An *o*-substituent produces a 7—13 nm decrease in $\lambda_{max.}$ in water in comparison with the *m*-substituted compound. Models show that there are steric interactions between the *o*-substituents on the aromatic ring and the protons on the nitrogen atom and at C-4 of the enaminone system. Thus the plane of the aromatic ring is twisted away from the plane of the enaminone system, and the electronic interaction is reduced. Normal hypsochromic shifts on protonation of *o*-substituted compounds were observed. Only for the *o*-hydroxy-compound (16) was there a significant change in the

[1] J. V. Greenhill, M. Ramli, and T. Tomassini, *J.C.S. Perkin I*, 1975, 588.

[2] K. Dixon and J. V. Greenhill, *J.C.S. Perkin I*, following paper.

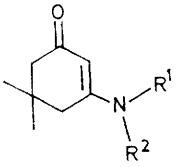
[3] N. J. Leonard and J. A. Adamcik, *J. Amer. Chem. Soc.*, 1959, **81**, 595; H. E. A. Kramer and R. Gompper, *Tetrahedron Letters*, 1963, **15**, 969.

[4] G. H. Alt and A. J. Speziale, *J. Org. Chem.*, 1965, **30**, 1407.

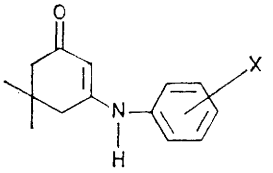
[5] J. V. Greenhill, *J. Chem. Soc.* (*B*), 1969, 299; O. Nielands, *Latvijas P.S.R. Zinatnu Adak. Vestis. kim. Ser.*, 1964, **5**, 577.

TABLE 1

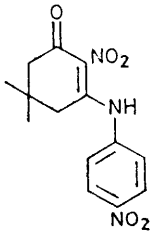
U.v. data



Compd.	R^1	R^2	0.1M-HCl λ_{max}/nm	0.1M-HCl ε	H_2O λ_{max}/nm	H_2O ε	0.1M-NaOH λ_{max}/nm	0.1M-NaOH ε	Ref.
(1)	H	H	276	21 500	287	26 400	288	26 400	*a*
(2)	Me	H	280	23 500	291	29 000	292	29 600	*a*
(3)	Me	Me	286	22 900	302	32 300	302	33 800	*a*
(4)	$[CH_2]_4$		288	24 600	304	35 600	304	35 600	3
(5)	$[CH_2]_5$		290	29 400	308	39 700	308	41 400	*b*
(6)	$[CH_2]_2{\cdot}O{\cdot}[CH_2]_2$		295	27 200	307	35 100	307	35 100	4



	X					
(7)	H	299	21 400	309	23 900	308	23 700	*c*
(8)	*o*-Me	292	24 100	299	28 000	299	27 000	
(9)	*m*-Me	299	21 700	310	24 700	309	24 000	
(10)	*p*-Me	299	22 400	309	25 900	308	25 600	
(11)	2,4-Me_2	293	22 800	299	27 600	299	27 600	
(12)	2,6-Me_2	290	24 100	296	28 300	296	27 800	
(13)	*o*-OMe	292	20 000	304	25 900	304	26 400	
(14)	*m*-OMe	298	20 500	312	23 000	310	22 500	
(15)	*p*-OMe	302	18 400	306	26 400	306	23 900	
(16)	*o*-OH	291	23 300	301	24 000	296	18 700	
(17)	*m*-OH	299	19 500	312	23 600	310	21 800	
(18)	*p*-OH	302	17 300	306	26 300	307	17 900	
(19)	*o*-Cl	294	22 000	299	24 700	301	25 200	
(20)	*m*-Cl	301	21 900	312	24 200	310	23 000	
(21)	*p*-Cl	301	21 900	312	23 800	311	23 300	
(22)	*o*-NH_2	294	23 200	298	24 500	297	24 300	
(23)	*m*-NH_2	303	20 000	310	21 000	310	20 700	
(24)	*p*-NH_2	302	23 300	307	23 100	307	22 600	
(25)	*o*-NO_2	298	21 500	305	20 500	304	22 300	
(26)	*m*-NO_2	302	23 000	312	24 500	307	23 200	
		288	14 300	286	15 100	296	18 700	
		346	13 500	370	17 700	370	10 100	
		M-HCl				M-NaOH		
(27)	*p*-NO_2	288	10 700			298	12 300	
		330	12 400			408	2 700	
		Conc. HCl						
		323	17 500					
		0.1M-HCl				0.1M-NaOH		
		302	17 900	301	18 000	305	20 000	
(28)	3,5-$(NO_2)_2$	M-HCl				M-NaOH		
		305	18 400			305	19 600	
		Conc. HCl						
		308	21 200					



		M-HCl						
(29)		276	13 000	274	12 000	348	14 100	
		339	13 000	338	12 000			
		Conc. HCl				M-NaOH		
		287	19 000			346	14 100	

[a] J. V. Greenhill, *J. Chem. Soc.* (C), 1971, 2699. [b] D. Pitea and G. Favini, *J.C.S. Perkin II*, 1972, 142. [c] K. Kotera, *J. Pharm. Soc. Japan*, 1960, **80**, 1275.

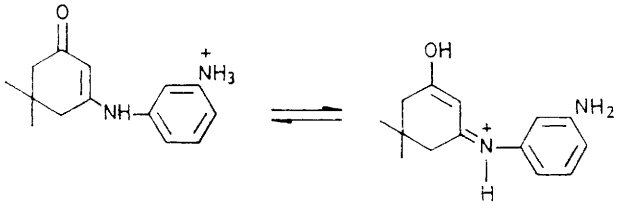
spectrum on passing from water to 0.1M-sodium hydroxide. Although there was a clear peak at 296 nm, the spectrum was characterised by a broad shoulder between 325 and 350 nm. The long wavelength absorption must be due to the phenolic anion, a very strong electron donor.

Compounds with *p*-substituents capable of mesomeric electron donation [(15), (18), and (24)] absorb at slightly lower wavelengths than the unsubstituted compound (7). Clearly the mesomeric effect is not relayed through the NH group, and the electron-withdrawing inductive effects of the substituents are seen. On protonation, however, a small donation is made from the substituent group and the hypsochromic shifts are only 4—5 nm.

Compound (18), like the *o*-compound (16), shows in 0.1M-sodium hydroxide a reduction in intensity of the peak accompanied by the appearance of a broad long-wavelength absorption. Once again this is due to an ionised phenolic group which is a very powerful electron donor. But even in M-sodium hydroxide the electron donation from the aromatic ring is too inefficient to produce a new long wavelength peak. (Neither spectrum changes at sodium hydroxide concentrations between 0.1 and 1M.)

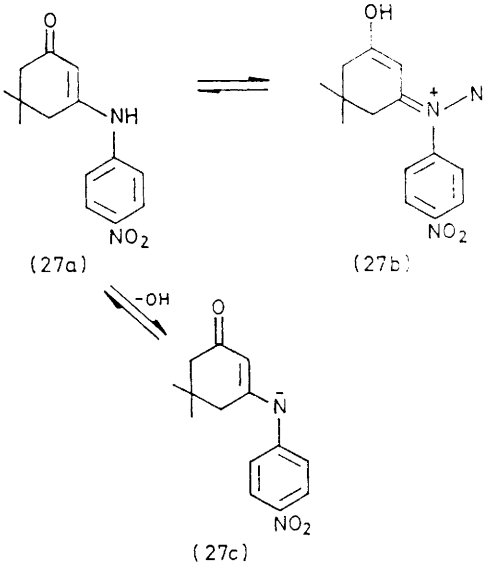
The three compounds with aromatic amino-substituents [(22)—(24)] show small shifts of 4, 7, and 5 nm, respectively, on protonation. If protonation were substantially on the amino-group an electron-withdrawing substituent would be formed, but very little effect on the absorption would be expected. From this one must assume that the *m*-amino-compound, if protonated on NH_2 (30a), would absorb at about 310 nm. In fact, absorption at 303 nm was observed, indicating that the *O*-protonated form (30b) is the major contributor to the equilibrium. It follows that compounds (22) and (24) are also, at least partially, *O*-protonated.

It was expected that the strongly electron-withdrawing nitro-group would produce some interesting effects. The *m*-nitro-compound (26) shows little difference from the unsubstituted enaminone (7). More surprising is the failure of the *o*-nitro-substituent [compound (25)] greatly to affect the spectra. The twisting of the aromatic ring away from the plane of the cyclohexenone



(30a) (30b)

ring must be enough to prevent the relay of the nitro-group's effect into the enaminone system. The compound with a *p*-nitro-group (27) has very different spectral properties from any previously seen. In water there are two peaks, at 286 and 370 nm. The former is in the same position as that of the primary enaminone (1). It must be due to the enaminone system, with the aromatic substituent having no auxochromic effect. *p*-Nitroaniline in aqueous solution absorbs [6] at 382 nm (ε 12 300). The peak at 370 nm (ε 17 700) seen for compound (27) must be due to the *p*-nitroaniline part of the molecule. The *p*-nitro-group has a base-weakening effect and the spectrum was seen to change in passing from 0.1M- to M- to concentrated hydrochloric acid. Even in concentrated hydrochloric acid protonation was



(27a) (27b) (27c)

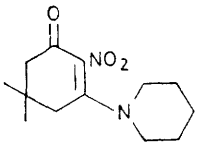
probably incomplete, as a very broad peak was observed. (Neither the *o*- nor the *m*-nitro-compound showed any similar change in more concentrated acid.) As the acid concentration increased, the peak at 286 nm decreased in intensity but remained at the same position. The peak at 370 nm (water) shifted to 323 nm (conc. HCl). Absorption due to the *p*-nitroaniline group would be at lower wavelength for the form (27b) where the charged nitrogen atom is unable to donate negative charge to the aromatic ring. The enaminone peak due to form (27a) is clearly visible in M-hydrochloric acid but cannot be distinguished in the spectrum in concentrated hydrochloric acid. In 0.1M-sodium hydroxide there was no significant change from the neutral spectrum but in M-sodium hydroxide a small new peak at 408 nm appeared. This was the first example of an enaminone showing acidic properties in aqueous solution: the anion (27c) would be stabilised by resonance with the carbonyl and nitro-groups.

Compound (28) has nitro groups in both *m*-positions. The electron-withdrawing effect is powerful enough to shift the peak in water by 8 nm in comparison with the unsubstituted compound (7). The two nitro-groups also weaken the base so much that no significant protonation occurs. The slight increase in the wavelength of the peak in passing from 0.1M- to concentrated hydrochloric

[6] J. P. Idoux and C. K. Hancock, *J. Org. Chem.*, 1968, **33**, 3498.

acid may be due to the increased polarity of the medium (in ethanol the compound absorbs at 296 nm).

When compound (7) was treated with nitrating mixture below 5 °C only a dinitro-derivative (29) could be isolated. We had previously observed [7] for compound (31) that the nitro-substituent in the enaminone



(31)

system produces a neutral compound. The figures $\lambda_{max.}$ 283.5 nm (ε 12 600) were seen in both water and 0.1M-hydrochloric acid. For compound (29), therefore, the peak at 274 nm is due to the enaminone system and that at 338 nm to the *p*-nitroaniline system with, this time, the 2-nitro-enone system acting as a more powerful electron-withdrawing auxochrome. Although no change is seen in the spectrum in M-hydrochloric acid, the long wavelength peak is suppressed in concentrated hydrochloric acid, possibly owing to *N*-protonation. As might be expected from the results on compound (27), this dinitro-derivative ionises as an acid and this is complete in 0.1M-sodium hydroxide. The shorter wavelength of this peak (348 nm) is due to the strong electron-withdrawing effect of the nitro-group in the cyclohexenone ring.

EXPERIMENTAL

The u.v. spectra were recorded with a Unicam SP 800 spectrometer. Solutions (*ca.* 4 × 10^{-4}M) of enaminone in ethanol were prepared. These were accurately diluted with the appropriate solvent (10 to 100 ml) and the spectra were recorded immediately. For solutions in 0.1M-acid or -alkali, M-hydrochloric acid or -sodium hydroxide (10 ml) was added during the dilutions. The solutions were kept at room temperature and the spectra re-run at suitable time intervals. In acidic solution the spectra changed owing to hydrolysis but in no case was this significant after 15 min; determinations with fresh solutions thus gave reliable results.

Preparation of Enaminones.—Method A. A solution of dimedone (10 mmol) and the substituted aniline (10 mmol) in benzene (50 ml) was refluxed under a Dean–Stark water separator until no more water was collected (2—8 h). For compounds (12), (13), (20), and (26), xylene was used as solvent. The solvent was evaporated off and the *product* recrystallised from the solvent given in Table 2.

Method B. A solution of compound (26) (5 g) in methanol (100 ml) was hydrogenated over 5% palladium–charcoal (2.5 g) for 2 h. Filtration and evaporation gave *compound* (23).

TABLE 2

Analytical data for enaminones

Compd.	Method	Yield (%)	M.p. (°C)	Solvent	Required (%) C	Required (%) H	Required (%) N	Found (%) C	Found (%) H	Found (%) N
(8)	A	54	136	EtOAc	78.6	8.2	6.1	79.0	8.3	5.9
(9)	A	72	155—156	EtOAc	78.6	8.2	6.1	78.4	8.2	6.2
(10)	A	74	203—204	EtOH	78.6	8.2	6.1	78.4	8.4	6.0
(11)	A	44	172—173	EtOAc	79.0	8.6	5.8	79.3	8.4	5.8
(12)	A	18	198	EtOAc	79.0	8.6	5.8	79.1	8.6	5.8
(13)	A	75	136—137	EtOAc	73.5	7.8	5.7	73.6	7.7	5.7
(14)	A	69	111—112	C_6H_6	73.5	7.8	5.7	73.6	7.8	5.7
(15)	A	69	191—192	MeCOEt	73.5	7.8	5.7	73.9	7.6	5.7
(16)	A	59	236—237	EtOH	72.7	7.4	6.1	72.7	7.3	6.0
(17)	A	78	241—224	EtOH	72.7	7.4	6.1	72.8	7.4	6.1
(18)	A	82	250—251	EtOH	72.7	7.4	6.1	72.8	7.5	6.1
(19)	C	24	141—142	EtOAc	67.3	6.4	5.6	67.4	6.5	5.6
(20)	A	40	152—153	EtOAc	67.3	6.4	5.6	67.4	6.5	5.7
(21)	A	22	209—210	EtOAc	67.3	6.4	5.6	67.5	6.4	5.5
(22)	A	50	178—179	EtOAc	73.0	7.8	12.2	72.8	8.0	12.2
(23)	B	61	230—231	EtOH	73.0	7.8	12.2	73.0	7.8	12.2
(24)	A	54	212—213	EtOH	73.0	7.8	12.2	73.2	7.6	12.2
(25)	C	46	163—164	C_6H_6	64.6	6.2	10.8	64.8	6.2	10.8
(26)	A	41	174—175	$CHCl_3$	64.6	6.2	10.8	64.6	6.1	10.8
(27)	C	20	246—247	$CHCl_3$	64.6	6.2	10.8	64.3	6.1	10.4
(28)	C	16	278—279	HOAc	55.1	4.9	13.8	55.3	5.0	13.9
(29)	D	71	198—199	HOAc	55.1	4.9	13.8	55.1	5.0	13.8

Method C. A solution of 5,5-dimethyl-3-methoxycyclohex-2-enone [2] (10 mmol), the aniline derivative (10 mmol), and 14% boron trifluoride in methanol (5.6 ml) in methanol (25 ml) was refluxed for 24 h, then evaporated under vacuum. The residue was taken up in ethyl acetate. The solution was washed with 5% sodium hydroxide and water and evaporated. The *product* was recrystallised from the solvent given in Table 2.

Method D. A mixture of compound (7) (2 g) and concentrated sulphuric acid (7 ml) was stirred on an ice-bath. Concentrated nitric acid (2 ml) was added over 10 min and stirring was continued at room temperature for 1 h further. The product was poured into water (100 ml) and extracted with methylene chloride (4 × 50 ml). The combined extracts were washed (H_2O), dried ($MgSO_4$), and evaporated to give *compound* (29).

I thank Mr. R. Smith for technical assistance.

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[7] K. Dixon and J. V. Greenhill, *J.C.S. Perkin II*, 1974, 164.