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Synthesis, Properties, and Thermodynamic Ionization Constants of α-Phenylstyrylacrylohydroxamic Acids

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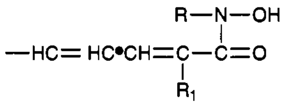
The synthesis and properties of eight new hydroxamic acids derived from α-phenylstyrylacrylic acids are described. These hydroxamic acids, which are crystalline compounds, were characterized by their ultraviolet, infrared, and NMR spectra. The purity was checked by HPLC and HPTLC. The nonaqueous titrations and alkaline hydrolysis are reported. Thermodynamic ionization constants at (25 and 35 ± 0.1) °C are determined. Preliminary studies show that these acids form a chloroform-extractable violet complex with vanadium(V) in 6 M hydrochloric acid solutions.

Hydroxamic acids are versatile reagents for trace metal ions (*1–6*). It has been also observed that introduction of the C-phenyl ring alters the reactivity of hydroxamic acids toward the metal ions (*7, 8*). In the present investigation a new series of hydroxamic acids (**I**), introducing the α-phenyl ring at the tertiary carbon atom of the C-phenyl ring and having superior reagent properties, are synthesized. In **I**, R = phenyl-, *p*-tolyl-, *m*-tolyl-, *p*-chlorophenyl-, *m*-chlorophenyl-, or *p*-bromophenyl- and R_1 = phenyl or *p*-chlorophenyl.



$$-HC{=}HC{\bullet}CH{=}\underset{\displaystyle R_1}{C}-\overset{\displaystyle R-N-OH}{C}{=}O$$

I

Experimental Section

Chemicals and Reagents. All chemicals used were of G.R. and AnalaR grades of E. Merck and BDH, respectively, unless otherwise specified.

Pure distilled water, redistilled over alkaline potassium permanganate and free from carbon dioxide, was used. It was tested for the absence of carbonate according to Kolthoff's method (*9*). Dioxane was purified according to the procedure of Vogel (*10*).

Apparatus. The UV absorption spectra were recorded on a Hitachi 3210 spectrophotometer. Infrared spectra were recorded as KBr pellets on a Shimadzu IR 408 spectrophotometer. Proton NMR spectra were recorded on a Varian T-60 spectrophotometer operating at 60 MHz for protons, in $CDCl_3$ with tetramethylsilane as internal standard. A Chrompack HPLC equipped with a CPISOS/GRAS LC pump, a Chrompack UV-VAR detector (190–800 nm), and a Rheodyne microliter syringe loaded sample value Model 7125 with a Shimadzu C-R6A integrator was used. Precoated TLC plates of E. Merck, silica gel 60 F 254 on aluminum sheets, thickness 0.2 mm, were used. CAMAG LINOMATE IV was used for sample application, and a CAMAG TLC Scanner II with computer controller CAMAG TLC evaluation software was used. A Radiometer pH meter (PHM 84) equipped with a combined electrode was used for pH-metric titrations. The pH meter was calibrated as described elsewhere (*11, 12*).

TG and DTA curves of α-phenylstyrylacrylohydroxamic acids were recorded on a Mettler thermal analyzer maintaining the following instrumental factors: TG range, 1 mg full scale sensitivity; DTA range, 50 μV; heating rate, 6 °C min^{-1}; air flow rate, 100 mL min^{-1}.

Preparation of α-Phenylstyrylacrylic Acid. This compound was prepared by the reaction of cinnamaldehyde with phenylacetic acid and acetic anhydride (*13*).

Preparation of Acid Chloride. The acid chlorides were prepared by the action of thionyl chloride on the corresponding α-phenylstyrylacrylic acids and refluxing them on a water bath for 4–5 h; the excess thionyl chloride was distilled off under vacuum. The yield and melting point are in agreement with the literature (*14*). *N*-Phenyl-, *p*-tolyl-, *m*-tolyl-, *p*-chlorophenyl-, *m*-chlorophenyl-, and *p*-bromophenylhydroxylamines were freshly prepared as described elsewhere (*15–20*).

Preparation of N-Phenyl-α-phenylstyrylacrylohydroxamic Acid. *N*-Phenylhydroxylamine (1.09 g, 0.01 mol) was dissolved in 20 mL of diethyl ether, and a fine suspension of 1.68 g (0.02 mol) of sodium bicarbonate in 15–20 mL of water was added and stirred with a magnetic stirrer with external cooling to lower the temperature to 0 °C or below. Then 2.68 g (0.01 mol) of the α-phenylstyrylacryl chloride dissolved in 50 mL of diethyl ether was added dropwise over a period of 30 min. The reaction mixture was then stirred for an additional 15 min and the temperature kept low to prevent possible side reactions. Some of the product was separated as yellow solid while the ethereal layer was separated and removed under reduced pressure. The yellowish-red residue thus obtained was combined with the precipitated yellow product, titurated for about 15 min with a saturated solution of sodium bicarbonate to remove the acid impurities, filtered, washed with cold water, and air-dried, mp 36 °C. Two crystallizations from a mixture of toluene and petroleum ether gave a white compound (yield 65%), mp 39 °C.

***Colorimetric Test** (21).* The standard vanadium solution was extracted (in 6 M HCl) with a known volume of α-phenylstyrylacrylohydroxamic acid (in chloroform). The bluish-violet color was separated and diluted to 25 mL with chloroform; its absorbance was measured against reagent blank, and the concentration of hydroxamic acid was estimated.

Nonaqueous Titration. α-Phenylstyrylacrylohydroxamic acid was dissolved in dimethylformamide (50 mL) and titrated with 0.1 M sodium methoxide using thymol blue as indicator and potentiometrically titrated by using a

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Table 1. Properties of α-Phenylstyrylacrylohydroxamic Acids

compd no.	α-phenylstyrylacrylohydroxamic acid	mp, °C	yield	color	UV λ_{max} EtOH, nm	UV $\epsilon \times 10^{-4}$ L mol^{-1} cm^{-1}	IR frequencies, cm^{-1} ν_{OH}	$\nu_{C=O}$	ν_{C-N}	ν_{N-O}	PMR δ, ppm OH	CH-CH multiplet
I	*N*-phenyl-	39	65	white	328	1.7	3320	1645	1375	940	10.7	7.22
II	*N*-*p*-tolyl-	70	70	white	332	2.2	3350	1645	1370	930	10.9	7.30
III	*N*-*m*-tolyl-	32	58	white	335	2.0	3250	1650	1365	935	10.6	7.27
IV	*N*-*p*-chlorophenyl-	170	75	white	325	1.4	3300	1640	1370	930	10.5	7.35
V	*N*-*m*-chlorophenyl-	35	62	white	327	2.4	3325	1635	1360	940	10.8	7.28
VI	*N*-*p*-bromophenyl-	116	71	light yellow	329	1.5	3350	1630	1360	925	10.8	7.74
VII	*N*-phenyl-*p*-chloro-	118	73	white	325	2.3	3270	1650	1370	930	10.6	7.24
VIII	*N*-*p*-chlorophenyl-*p*-chloro-	65	76	white	329	2.2	3200	1620	1350	920	10.7	7.35

Table 2. Thermodynamic Ionization Constants and Analytical Data on α-Phenylstyrylacrylohydroxamic Acid

compd no.	pK_a^{a} at 25 °C	nonaqueous titration molecular wt theor	found potentiometry	found visual	DTA, °C endo	exo	TG wt loss, °C	HPLC RT, min	HPLC purity, %	HPTLC peak no.	area	purity	vanadium extraction λ_{max}, nm	$\epsilon_{max} \times 10^3$ L mol cm^{-1}	*k* (*k*/min × 10^{-3})
I	11.52 (11.28)	341.41	341.2	340	40	200	180–230	4.43	99.69	2	903	99.70	548	2.0	6.8
II	11.73 (11.48)	355.44	355.5	355	72	238	200–330	4.88	99.48	2	925	99.50	549	1.6	6.0
III	11.58 (11.36)	355.44	355.0	354	32	150	108–250	4.63	97.54	2	940	97.53	550	1.5	5.8
IV	11.30 (11.05)	376.58	376.5	376	170	360	200–500	3.81	99.98	2	900	99.97	553	7.8	8.0
V	11.20 (10.96)	375.86	375.5	375	36	155	190–300	3.79	99.09	2	930	99.10	545	4.3	8.5
VI	11.08 (10.88)	420.31	420.6	421	116	300	160–380	3.50	99.17	2	928	99.19	550	4.0	9.0
VII	11.32 (11.08)	375.86	375.7	376	118	325	205–500	3.91	98.92	2	938	98.90	552	3.5	7.0
VIII	11.06 (10.85)	413.30	413.1	414	65	220	100–400	3.33	99.56	2	924	99.55	545	3.2	9.8

[a] The values given in the parentheses are at 35 °C.

platinum and calomel electrode (saturated KCl in methanol) in the presence of nitrogen.

Ionization Constants. These were determined at 25 and 35 °C in a 70% dioxane–water medium. The procedure and calculation methods as given by Agrawal (*22–24*) were followed. The ionization of α-phenylstyrylacrylohydroxamic acid (HA) in aqueous solution gives hydrogen ion and hydroxamate ion and the equilibrium constant may be

$$K_{a(aq)} = [H^+][A^-]/[HA]Y_{H^+}Y_{A^-}/Y_{HA} \quad (1)$$

or

$$pK_a = -\log [H^+] + \log [HA]/[A^-] - 2 \log Y_{\pm} \quad (2)$$

Assuming the activity coefficient of un-ionized acid is unity and obtained from the data of Harned and Owen (*25*), the empirical correction for medium effect as suggested by Van Uitert and Haas (*26*) and Agrawal (*20*), $-\log [H^+] = B + \log U_H{}^0 + \log Y_{\pm}$, was used to obtain the hydrogen ion concentration. The final form of the equation for calculating the ionization constants in dioxane–water media is

$$pK_a = B + \log U_H{}^0 + \log [HA]/[A^-] - \log Y_{\pm} \quad (3)$$

where B is the pH meter reading and the value of $\log U_H{}^0$ is determined experimentally (*27*).

In a thermostated condition (25 or 35 ± 0.1 °C) using combined glass and calomel electrodes, 0.5 mmol of α-phenylstyrylacrylohydroxamic acid in the solvent 70% dioxane–water (47.5 mL) was titrated with 0.1 M tetrabutylammonium hydroxide, which too was prepared in 70% dioxane–water. After deaeration by passage of nitrogen (presaturated with 70% dioxane–water) for 15 min, the highest pH meter reading (B value) was noted after each increment.

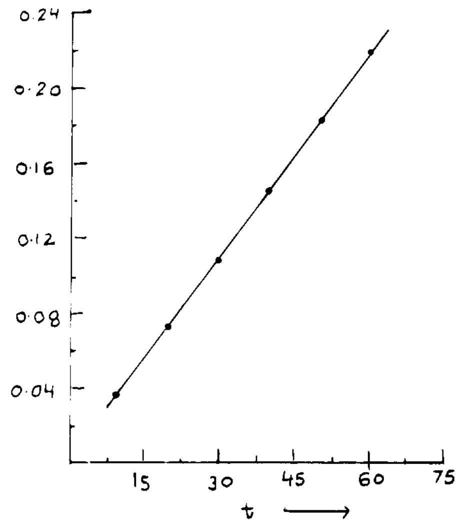


Figure 1. Plot of $\log[(A_0 - A_\infty)/(A_t - A_\infty)]$ vs time (t).

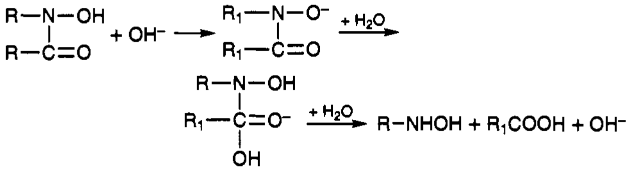
Kinetic Studies. Into a thermostated (35 ± 0.1 °C), 50-mL B-24 conical flask were added 10 mL each of 0.01 M α-phenylstyrylacrylohydroxamic acid in methanol and 0.10 M sodium hydroxide. One milliliter aliquots of this reaction mixture were withdrawn at regular intervals of 30 min, starting from the time of mixing, considered as zero time, and then complexed with 2 mL of $FeCl_3$ solution (2% w/v). The complex was then diluted to 25 mL with distilled water. Absorbance (A_t) was measured at the λ_{max} for the respective hydroxamic acid–Fe(III) complex. The absorbance at infinite time (A_∞) was measured, keeping the reaction mixture for 48 h. The rate constant (k) was calculated from

$$k = (2.303/t)\log[(A_0 - A_\infty)/(A_t - A_\infty)]$$

Results and Discussion

The properties of α-phenylstyrylacrylohydroxamic acids are given in Table 1. The analytical data on hydroxamic acids are summarized in Table 2.

The ultraviolet spectra of these acids show a distinct band around (327 ± 2) nm. The infrared spectra of the acids show bands at (3250 ± 50) cm^{-1} (OH), (1635 ± 15) cm^{-1} (C=O), (1665 ± 15) cm^{-1} (C—N), and (930 ± 10) cm^{-1} (N—O) absorption, which are similar to those reported earlier (*15–19*). The purity of these acids is checked by HPTLC and HPLC (Table 2), which have retention times around (4 ± 0.5) min with a single peak and of purity 99%. The rate constants of the alkaline hydrolysis of these acids are of pseudo first order (*28*) and represented by the possible following mechanism:



The plot of $(A_0 - A_\infty)/(A_t - A_\infty)$ vs time (t) (Figure 1) showed linearity in cases of all acids, which further confirmed that the hydrolysis reaction is of first order.

The pK_a values of α-phenylstyrylacrylohydroxamic acids in 70% (v/v) dioxane–water media at (25 and 35 ± 1) °C are given in Table 2. The average pK_a generally falls within ±0.03. The pK_a at lower percent of dioxane could not be determined since these acids are insoluble in less than 70% dioxane–water media. The pK_a values follow the order of substitution; a methyl group has a positive inductive and mesomeric effect, which weakens the acid strength, while a chloro group is electronegative and has a positive inductive effect, which increases the acid strength. Hence, the pK_a values have the following order ($CH_3 > Cl \sim Br$):

$$\text{II} > \text{III} > \text{I} > \text{VII} > \text{IV} > \text{V} > \text{VI} > \text{VIII}$$

A similar order has been observed for the rate constants as order of K:

$$\text{VIII} > \text{VI} > \text{V} > \text{IV} > \text{VII} > \text{I} > \text{III} > \text{II}$$

Further, the rate constant is studied in different solvent media and base. The data given Table 3 show that in completely nonaqueous medium the rate constant considerably decreases.

Table 3. Effect of Solvent and Base Catalyst in Rate Constant of *N*-*p*-Chlorophenyl-α-phenylstyrylacrylohydroxamic Acid

solvent (%)	base	k/min × 10^{-3}	$t_{0.5}$
methanol (50)	0.01 M KOH	8.0	82.5
	0.02 M KOH	8.0	82.5
	0.20 M KOH	7.9	83.0
	0.50 M KOH	7.9	83.3
methanol (70)	0.20 M KOH	7.7	88.0
methanol (90)	0.10 M KOH	6.9	100.0
methanol (90)	0.10 M ethanolamine	6.3	110.0
methanol (90)	0.10 M ethylenediamine	6.0	115.0
methanol (100)	0.10 M ethanolamine	1.7	407.0
methanol (100)	0.10 M ethylenediamine	2.0	301.0
dioxane (50)	0.02 M KOH	7.0	90.0
dioxane (50)	0.20 M KOH	7.0	90.0

Literature Cited

(1) Agrawal, Y. K. *Rev. Anal. Chem.* **1980**, *5*, 3.
(2) Agrawal, Y. K.; Roshania, R. D. *Bull. Soc. Chim. Belg.* **1980**, *87*, 261.
(3) Agrawal, Y. K.; Patel, S. A. *Rev. Anal. Chem.* **1980**, *4*, 237.
(4) Agrawal, Y. K.; Jain, R. K. *Rev. Anal. Chem.* **1982**, *6*, 49.
(5) Majumdar, A. K. *N-Benzoylphenylhydroxylamine and its Analogues*; Pergamon Press: London, 1971.
(6) Shendrikar, A. D. *Talanta* **1969**, *16*, 51.
(7) Agrawal, Y. K.; John, K. T. *J. Chem. Eng. Data* **1985**, *30*, 403.
(8) Bhura, D. C.; Tandon, S. G. *Anal. Chim. Acta* **1971**, *53*, 379.
(9) Kolthoff, I. M.; Sandell, E. B. *Text-Book of Quantitative Inorganic Analysis*; MacMillan: London, 1952; p 517.
(10) Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R. *Vogel's Text-Book of Practical Organic Chemistry*, 5th ed.; Longman: Birmingham, AL, 1989.
(11) Perrin, D. D.; Dempsey, B. *Buffers for pH and Metal ions control*; Chapman Hall: London, 1974.
(12) Gentile, P. S.; Cefola, M.; Cellano, A. V. *J. Phys. Chem.* **1963**, *67*, 1083.
(13) Buckles, R. E.; Bellis, M. P.; Coder, W. D., Jr. *J. Am. Chem. Soc.* **1951**, *73*, 4972.
(14) Ottmar, Wahl.; Johannes, Goetze. *Chem. Abstr.* **1962**, 11116 h.
(15) Agrawal, Y. K.; Tandon, S. G. *J. Chem. Eng. Data* **1971**, *16*, 371.
(16) Agrawal, Y. K.; Tandon, S. G. *J. Chem. Eng. Data* **1971**, *16*, 445.
(17) Agrawal, Y. K. *J. Chem. Eng. Data* **1977**, *22*, 70.
(18) Jain, R. K.; Agrawal, Y. K. *J. Chem. Eng. Data* **1979**, *24*, 250.
(19) Roshania, R. D.; Agrawal, Y. K. *J. Chem. Eng. Data* **1978**, *23*, 259.
(20) Mudaliar, A.; Agrawal, Y. K. *J. Chem. Eng. Data* **1979**, *24*, 246.
(21) Agrawal, Y. K. *Anal. Chem.* **1975**, *47*, 940.
(22) Agrawal, Y. K. *Russ. Chem. Rev.* **1979**, *48*, 1773.
(23) Agrawal, Y. K.; Tandon, S. G. *Talanta* **1972**, *19*, 700.
(24) Agrawal, Y. K. D.Sc. Thesis, A.P.S. Univ. Rewa, 1979.
(25) Harned, H. S.; Owen, B. B. *The Physical Chemistry of Electrolytic Solutions*; Reinhold: New York, 1958; pp 161, 536, 662, 714, 717, 750.
(26) Van Uitert, L. G.; Haas, C. G. *J. Am. Chem. Soc.* **1953**, *75*, 451.
(27) Agrawal, Y. K. *Talanta* **1973**, *20*, 135.
(28) Berndt, D. C.; Fuller, R. J. *J. Org. Chem.* **1966**, *31*, 3312.

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