Communications to the Editor

Chem. Pharm. Bull.
29(6)1772—1774(1981)

Oxidation Potential Shift as a Measure of Hydrogen-Bonding and/or the Basicity[1]

Difference of anodic oxidation potentials of hydroxamic acid between those in the absence and presence of a base depends on the strength of hydrogen-bonding between the acidic proton and base, being a measure of hydrogen-bonding and relative basicity of the base in the medium.

Keywords——hydrogen-bonding; hydroxamic acids; anodic oxidation; potential shift; base strength; cyclic voltammetry

The cyclic voltammogram of acid amide[2] and hydroxamic acid[3] showed an extra irreversible peak at less positive potentials (E_{pe}) than the original first peak (at E_{pl}) corresponding to irreversible two electron transfer in the presence of added base, and the extra wave was considered to be due to the partial ionization of the acidic proton of the compounds. In order to study further details of the potential shift, $\Delta E_{\mathrm{p}}=E_{\mathrm{pl}}-E_{\mathrm{pe}}$, we used in the present study a series of hydroxamic acids and found that the potential shift can be used as a measure of hydrogen bonding between a weak acid and a base and/or the basicity of weak proton acceptors in organic solvent system.

Hydroxamic acids, $R_1CON(OR_2)R_3$, used are, I; $R_1=C_6H_5$, $R_2=R_3=H$, II; $R_1=p\text{-}NO_2\text{-}C_6H_4$, $R_2=R_3=H$, III; $R_1=C_6H_5$, $R_2=Me$, $R_3=H$, IV; $R_1=R_3=C_6H_5$, $R_2=H$, and V; $R_1=R_3=Me$, $R_2=H$. Amines used are those shown in Table.

TABLE

No.	Substance	pK_a	No.	Substance	pK_a
1	Isopropylamine	10.72[a]	10	α-Picoline	6.0[a]
2	*n*-Butylamine	10.61[c]	11	β-Picoline	5.7[a]
3	Trimethylamine	9.74[a]	12	Benzimidazole	5.50[b]
4	Monoethanolamine	9.44[a]	13	Quinoline	4.80[a]
5	Benzylamine	9.37[a]	14	3-Acetylpyridine	3.26[c]
6	Ammonia	9.25[a]	15	Pyrazole	2.52[c]
7	4-Aminopyridine	9.20[b]	16	3-Cyanopyridine	1.50[c]
8	γ-Collidine	7.30[d]	17	Acetamide	1.40[c]
9	Imidazole	7.0[b]			

[a] R.C. Weast, "Handbook of Chemistry and Physics," 47th Ed. The Chemical Rubber Co., 1966.
[b] S. Sasaki, "The Chemistry of Heterocyclic Compounds," Tokyokagakudojin Co., 1972.
[c] D.D. Perrine, "Dissociation Constants of Organic Base in Aqueous Solution: Supplement 1972," Butterworth and Co. Ltd. 1972.
[d] P.G. Stecher, "The Merck Index", 8th Ed., Merck and Co., Inc. 1968.

Cyclic voltammetry of the acids (1 mM or 5 mM) was carried out in dry acetonitrile containing sodium perchlorate (0.1 M) with a glassy-carbon electrode at 25±0.05 and a scan rate of 50 mV sec^{-1}. The first oxidation potential, E_{pl}, of the acids measured *vs.* SCE and the pK_a values cited,[4,5] shown in parentheses, are I=1.63 V (8.84), II=1.57 V (8.02), III=1.33 V (8.89), IV=1.05 V (9.15) V=1.63 V (8.84). Comparing the above values for I—IV, the acid with a larger pK_a have a more cathodic E_{pl}. The dependence of the peak current of the extra wave on the base concentration is illustrated in Fig 1. The height of the extra wave reaches to a constant value at a nearly fixed potential when more than about two to three times of the base is present and the height is nearly the same as that of the original first peak. At the time, it is not possible to observe whether the original first peak is still present or not because of the complex voltmmogram above the potential of E_{pl} region, but the disappearance

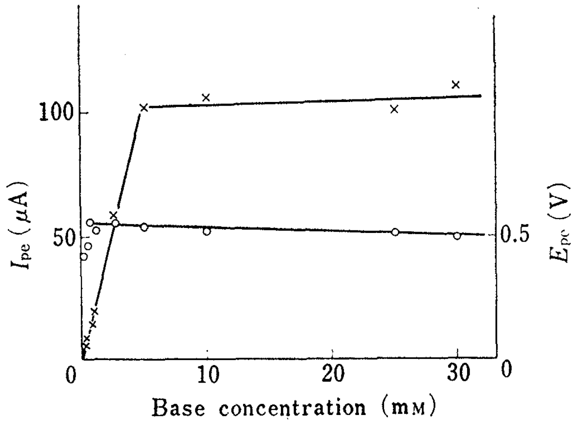


Fig. 1. Dependence of Peak Current and Peak Potential of the Extra Wave for BHA (5 mM, 50 mV/sec) on Concentration of Base (Collidine), × : I_{pe}, ○: E_{pe}

The potentials for the lower base concentration less than 0.5 mM are the shoulder potential of the ill defined wave.

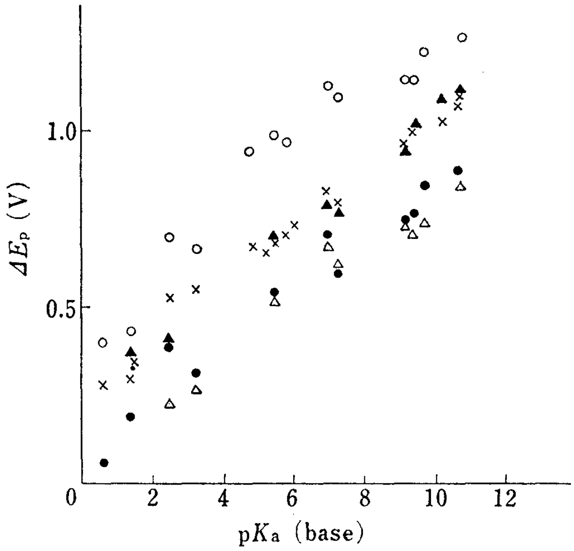


Fig. 2. Plot of ΔE_p against pK_a of the Added Base

I : ×, II : ○, III : ●, IV : △, V : ▲.

of the original first peak under the similar condition has been confirmed in the case of acid amide.[2] The variation of the wave height with sweep rate was measured using benzohydroxamic acid (BHA) in the presence of about five times of γ-collidine or isopropylamine. The values of $i_{pe}/CAV^{1/2}$ (A; area of electrode, C; concentration of BHA, V; sweep rate) slightly decreased with increase in sweep rate from 25 to 200 mV sec^{-1} by about 12 and 15%, respectively. The value of E_{pe} is rather independent of the base concentration (Fig. 1), whereas it highly depends on the base strength (Fig. 2). The potential and current behaviors observed as above (Fig. 1) cannot be explained by kinetic contribution supposed for the electrochemistry of the system $AH+B \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} A^-+BH^+$ where A^- is more easily oxidizable than AH,[6] though the kinetic contribution to the potential shift is not completely denied.

Plot of ΔE_p against pK_a of the added bases exihibits fairly excellent linearlity (Fig. 2), considering that so wide range of bases were choosen randomly and difference between the conditions used for measuring the ΔE_p and pK_a. The contamination of solvent, *e.g.*, with water, was found not to be serious, except for weaker base than acetamide. When added base is very weak, the intramolecular hydrogen-bonding between carbonyl and hydroxy groups of BHA will compete with hydrogen-bonding between base and BHA, and this may also be responsible for the scatter pattern observed in Fig. 2.

Ultraviolet spectra of BHA (1 mM) in acetonitrile showed no change on the addition of isopropylamine or acetamide (4 mM).[7] Infrared spectra of I, II, III, and IV (1 mM in dioxane) in the presence of isopropylamine or γ-collidine (1 mM each) measured with a NaCl cell (0.2 mm optical path) did not show appreciable shift larger than experimental error for the $\nu_{C=O}$ (near 1650 cm^{-1}).

The results may be explained by the following equilibrium, $A{-}H+nB \rightleftharpoons [\overset{-}{A}{-}H\cdots\overset{+}{B}n]$ where A—H is the free acid, B is the base and n is the number of base used to form hydrogen-bonded complex. In the complex $[\overset{-}{A}{-}H\cdots\overset{+}{B}n]$, hydrogen atom attached on the amino nitrogen or hydroxy oxygen of the hydroxamic acids should be hydrogen bonded with added base without changing the remaining part of the structure.[8] The hydrogen-bonding should produce negative charge on the nitrogen or oxygen with increasing extent of the proton transfer. Consequently, as the added base is stronger, the acid should be more susceptible to anodic oxidation. Thus the present results suggest that the ΔE_p will be a measure of the hydrogen-bonding, and a sensitive and simple method to know the relative strength of bases in organic solvent. This method is quite simple and should be useful for the system composed of both weak acid and base, especially for those where infrared spectroscopic method is not applicable because of overlapping of the absorption band caused by addition of organic base.

References and Notes

1) A part of this paper was presented at the 26th annual meeting on Polarography and Electroanalytical Chemistry, October 14th—15th 1980 in Fukuoka.
2) S. Ikenoya, M. Masui, H. Ohomori, and H. Sayo, *J.C.S. Perkin II*, **1974**, 571.
3) S. Ozaki and M. Masui, *Chem. Pharm. Bull.*, **25**, 1179 (1977).
4) O. Exner and W. Simon, *Collect. Czech. Chem. Commum.*, **30**, 4078 (1965).
5) J.D. Aubort and R.F. Hudson, *Chem. Commum.*, **1970**, 938.
6) R.S. Nicholson and I. Shain, *Anal. Chem.*, **36**, 706 (1964).
7) S. Nagakura (ed.), "Zikkenkagaku Koza," 2nd, **11**, ed. by Nihon Kagakukai, Maruzen Co. Ltd., Tokyo, 1965, p. 465.
8) R.W. Taft, G. Gurka, L. Jois, P. Von, Schlyer, and J.W. Rakshys, *J. Am. Chem. Soc.*, **91**, 4801 (1969).

Faculty of Pharmaceutical Sciences,
Osaka University
1-6, Yamada-Oka, Suita,
Osaka, 565, Japan

MASAICHIRO MASUI*
YORIE KAIHO
SHIGEKO OZAKI

Received January 24, 1981

Chem. Pharm. Bull.
29(6)1774—1776(1981)

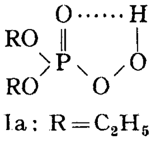
New Methods and Reagents in Organic Synthesis. 15.[1] Epoxidation of Olefins with Diethyl Phosphorocyanidate (DEPC) and Hydrogen Peroxide

A mixture of diethyl phosphorocyanidate (DEPC) and hydrogen peroxide in the presence of 2-hydroxypyridine or 1,2,4-triazole functions as an epoxidizing agent for olefins.

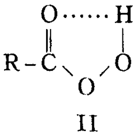
Keywords——diethyl phosphorocyanidate; hydrogen peroxide; epoxidation; 2-hydroxypyridine; 1,2,4-triazole; peroxyphosphoric acid

Recent efforts of our laboratories have unveiled that diethyl phosphorocyanidate (DEPC, $(C_2H_5O)_2P(O)CN$)[2] plays a role of a condensation-dehydration reagent[3] as well as a cyanation reagent.[4] Our continuing interest on the synthetic use of DEPC has led us to develop a new method for the epoxidation of olefins[5] using DEPC.

We have conceived that the action of DEPC on hydrogen peroxide would produce diethyl ester of peroxyphosphoric acid (Ia) which would have an epoxidizing power since it is isosteric to peroxycarboxylic acid (II). The only peroxyphosphoric acid ever known is peroxymonophosphoric acid (Ib)[6] which has been reported to epoxidize *trans*-stilbene.[7] However, its preparation is rather tedious and it is so acidic as to be apt to proceed the reaction further.



Ia: $R=C_2H_5$
Ib: $R=H$



II