[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF MOUNT HOLYOKE COLLEGE]

Electrometric Titration Curves of Certain Imino Dibasic Acids[1]

BY ANNE LITZINGER AND LUCY W. PICKETT

An investigation of the physical constants of the four imino dibasic acids which have been described[2] as having, respectively, the configurations $NH(CHC_6H_5COOH)CHCH_2C_6H_4OHCOOH$ (I), $NH(CH_2COOH)CHCH_2C_6H_4OHCOOH$ (II), $NH(CHC_6H_5COOH)CHCH_2C_6H_5COOH$ (III), and $NH(CH_2COOH)CHCH_2C_6H_5COOH$ (IV), was undertaken with a view to comparing them with iminodiacetic acid, $NH(CH_2COOH)_2$ (V). The latter is a substance of known structure and was prepared by hydrolyzing the corresponding dinitrile according to the method of Jongkees.[3] The other four acids, which may be regarded as phenylated derivatives of iminodiacetic acid, were obtained by hydrolyzing the corresponding substituted hydantoins.[4]

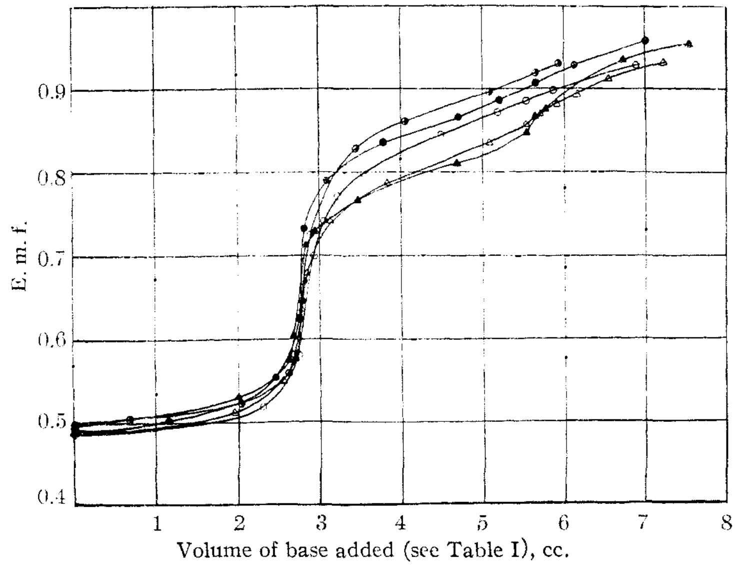

Fig. 1.—I, △; II, ○; III, ▲; IV, ●; V, ◑.

The titration curves which were obtained in the cases of these five acids are satisfactory in so far as their very marked similarity corresponds to the similarity in chemical properties. All show the greatest change in hydrogen-ion concentration at the first equivalence point and this probably accounts for the fact that diacetic acid and other acids belonging to the same general class[5] have been reported to be monobasic on the basis of titrations with phenolphthalein as indicator, although the acids prepared in this Laboratory yield dipotassium as well as mono-potassium salts.[6]

Experimental

Aqueous solutions of the acids were titrated directly with carbonate free potassium hydroxide (0.0355 *N*) and the course of the neutralization was followed potentiometrically using a hydrogen electrode and a decinormal calomel electrode with the usual precautions.[7] Due to very pronounced polarization, drifting and poisoning of the electrodes considerable time was often required to establish a final equilibrium. Nevertheless duplicate determinations gave titration curves which agreed with those presented in Fig. 1. In determining the apparent dissociation curves a saturated solution of known volume was used as a starting point in the experiment and titrations with water continued until the original volume was increased four times.

Data.—Titrations with base are presented in Table I and graphically in Fig. 1. The curves were obtained by plotting the electromotive force against the number of cc. of base added to samples of each of the five acids. Because of the hydroscopic nature of these acids, which made weighing difficult, it was not feasible to use equimolar quantities. In order to compare the titration curves it was, therefore, necessary to compute from the actual weight of acid used and the corresponding volume of base, the volume which would have been required if in each case 0.005 mole of the acid had been titrated.

---

[1] Grateful acknowledgment must be made to Dr. D. A. MacInnes of the Rockefeller Institute of Medical Research and to Dr. Margery K. Walker of Mount Holyoke College for their valuable assistance.

[2] Hahn and Litzinger, THIS JOURNAL, **54**, 4663 (1932).

[3] Jongkees, *Rec. trav. chim.*, **27**, 289 (1908).

[4] Hahn and Litzinger, *loc. cit.*, pp. 4664 and 4665.

[5] Stadnikoff, *Ber.*, **40**, 4351, 4354 (1907); **44**, 44 (1911); Ciamician and Silber, *ibid.*, **39**, 3948 (1906); Dubsky, *ibid.*, **49**, 1053 (1916); **54**, 2659 (1921).

[6] Jongkees never succeeded in preparing anything but a mono-potassium salt even on treating iminodiacetic acid with two equivalents of potash, *loc. cit.*, p. 293.

[7] These included the use of freshly prepared samples, pure hydrogen and conductivity water.

Although the result of these computations makes the volume scale in Fig. 1 different for each acid, any volume as read from the graph may be reconverted into the actual amount of base used by multiplying by the factors given in the fourth column of Table I. The values appearing in Column 5 of Table I represent the volumes of base added to give the first end-point as indicated by the pronounced break in the original titration curve of each acid. These values show good agreement with those theoretically required to neutralize one of the acid hydrogen atoms in each of the samples (Column 6).

TABLE I

Compound	Sample, g.	Titrated moles × 10^{-4}	Conversion factors	Base at first end-point, cc.	Base calcd. for one equiv., cc.	*P*H at first end-point
I	0.1490	4.731	4.74	13.25	13.30	5.21
II	.1564	6.543	6.54	18.51	18.41	5.34
III	.1143	3.822	3.82	10.69	10.75	5.30
IV	.1006	4.510	4.51	12.61	12.69	5.66
V	.0992	7.457	7.46	21.00	20.98	5.78

The *P*H values given in Column 7 were calculated from the electromotive force values corresponding to the volumes of Column 5.

In order to provide another basis of comparison the hydrogen-ion concentration was also determined for equimolar solutions of each acid. The results of these measurements are presented as *P*H values in Table II. The calculation of *pK* values from these data shows that *pK* is approximately 3.0 in each case and that the individual differences are small. Further conclusions from the measurements are not considered to be justified in view of the great dilution.[8]

TABLE II

COMPARISON OF *P*H OF EQUIMOLAR SOLUTIONS

Compound	I	II	III	IV	V
Concn. moles × 10^{-4}	3.94	3.94	3.95	3.90	4.21
*P*H	3.53	3.52	3.49	3.51	3.57

Figure 2 indicates the trend of the various dissociation constants with decreasing concentration. Due to the wide range in the solubilities of the different acids it was found necessary to plot each acid on a different concentration scale in order to facilitate comparison. The scale for the dissociation constants is, however, the same for all five acids. The respective units are indicated below the graph by means of the corresponding symbols. In the case of II the curve is so constructed as to include the points which lie along a smooth electromotive force–concentration curve, but is evidently not the only one possible from the data. In the case of the other four substances the data seem sufficiently unambiguous to warrant the curves presented.

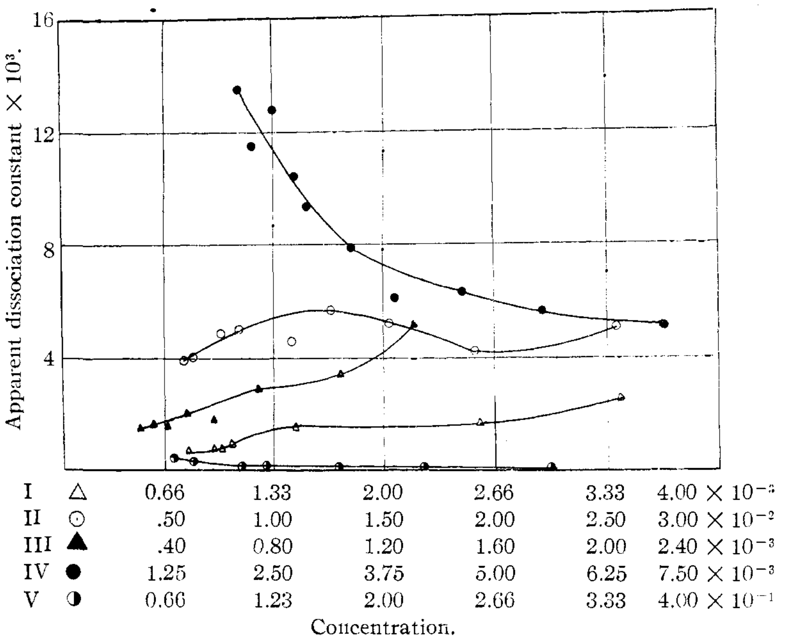

Fig. 2.

Discussion of Results.—The titration curves indicate that these five substances are essentially similar in their behavior as acids. In the case of tyrosine-N-phenylacetic acid and β-phenylalanine-N-phenylacetic acid there is unmistakable evidence of a second end-point corresponding to the addition of a second equivalent of base, and, since all the curves lie so close together throughout the entire range, it is not improbable that a second point of inflection occurs in the case of the other three acids but has been masked by the general insensitiveness of the hydrogen electrode in this region. It is also interesting to note that the monopotassium salts of the α-phenyl substituted

---

(8) The *pK* values are in rough agreement with those taken from independent colorimetric measurements where I = 3.1, II = 3.0, III = 3.6, IV = 3.0, V = 3.0. These measurements were carried out with equimolar solutions of salt and acid using brom phenol blue as indicator and were based on the approximate relationship $P_H = pK + \log [\text{salt}]/[\text{acid}]$.

acids show slightly greater acidity than the others.

The fact that the ionization constants were found to vary consistently with concentration led to an investigation of the ionization constants at equimolar concentrations. As indicated by the data in Table II the constants found agree closely, the magnitude showing that all five are weak acids with iminodiacetic the weakest. Closer investigation, as revealed by a study of Fig. 2, indicates, however, that the *manner* in which the apparent dissociation constants vary with changes in concentration is characteristically different in the case of each individual acid. For example, although the apparent dissociation constants decrease with increasing dilutions in the case of I and III, they increase under these conditions in the case of IV and V, while II seems to represent a superposition of these tendencies. In the case of the dilution curves the phenomena measured are admittedly complex since there are unknown chemical factors dependent on dilution; IV shows an abnormal behavior which may be indicative of decomposition. However, it is of interest and possibly of significance that I and III, which alone contain phenyl groups in the α-position, are similar in the above respect, while I and IV resemble each other and II is intermediate, a grouping which also suggests itself not only from their probable chemical constitution but from a comparison of the upper parts of their respective titration curves.

Summary

The electrometric titration curves of iminodiacetic acid and of four of its phenylated derivatives have been determined and have been found to be in close agreement, all showing the greatest change of *P*H at the point corresponding to the addition of one equivalent of base. A comparison of these curves shows that while the introduction of a phenyl group in the β-position is of minor importance, a phenyl group in the α-position corresponds to a relatively greater acidity of the mono-potassium salts and a distinct break in the curve at the second end-point. The dissociation constants as calculated agree closely and indicate that all five substances are weak acids. A comparison of their dilution curves shows characteristic variations for each acid.

SOUTH HADLEY, MASS. RECEIVED JULY 17, 1933

[CONTRIBUTION FROM BAKER LABORATORY OF CHEMISTRY AT CORNELL UNIVERSITY]

Reactions of 2-Halogen Ethers. I. The Action of Magnesium on Alkyl 2-Bromoethyl Ethers

BY RALPH C. TALLMAN

It has been known for some time that 2-halogen ethers when treated with metals give products other than those which might normally be anticipated. Grignard[1] using magnesium and later Wohl and Berthold[2] using sodium, found that 2-bromoethyl phenyl ether yielded as products, ethylene and phenol. In more recent years, Boord[3] and his co-workers have treated certain alkyl substituted 2-bromoethyl ethers with zinc dust for the preparation of various unsaturated hydrocarbons. Up to the present time, however, this reaction has not been studied using the simple alkyl 2-halogenethyl ethers with a view toward determining more accurately the course of the reaction and, if possible, explaining its mechanism in greater detail.

In the present paper are reported the results obtained by treating ethers of the type $R-O-CH_2-CH_2-Br$ with magnesium in the presence of anhydrous ethyl ether. The compounds investigated were those in which R is methyl, ethyl, *n*-propyl, isopropyl, *n*-butyl, isobutyl, *sec*-butyl and *n*-amyl. The behavior of these compounds toward magnesium is comparable with that of similar substances reported by previous workers, the products in the present cases being ethylene and the alkoxy magnesium bromide. In addition to these main products of the reaction, a quantity of material corresponding to the general formula $R-O-CH_2-CH_2-CH_2-CH_2-O-R$ was found to be present due to the action of part of the bromo ether in the Wurtz reaction.

---

(1) Grignard, *Compt. rend.*, **38**, 1048 (1904).

(2) Wohl and Berthold, *Ber.*, **43**, 2177 (1910).

(3) Boord and collaborators, THIS JOURNAL, (a) **52**, 651, 3396 (1930); (b) **53**, 1505, 2427 (1931); (c) **54**, 751 (1932); (d) **55**, 3293, 4930 (1933).