

# Reaction of ferric ions with nalidixic and *nor*-nalidixic acids

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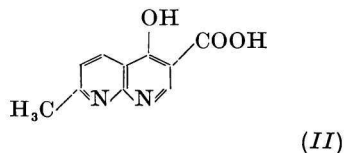
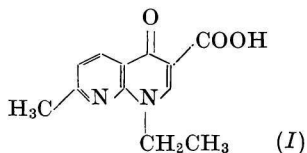
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*Dedicated to Professor MUDr F. Šantavý, DrSc, on his 60th birthday*

The reaction of Fe(III) ions with nalidixic and *nor*-nalidixic acids was studied. In acid medium, the formation of the 1:2 complex with nalidixic acid and the 1:1 complex with *nor*-nalidixic acid was proved and the conditional stability constants were determined. The reaction of Fe(III) ions with nalidixic acid was utilized for analytical purposes.

Исследовались реакции ионов железа(III) с налидиксовой и *нор*-налидиксовой кислотами. Было доказано, что в кислой среде образуется комплекс с налидиксовой кислотой с соотношением компонентов 1:2, и с *нор*-налидиксовой кислотой в той же среде с соотношением компонентов 1:1. Для обоих веществ были определены условные константы устойчивости. В среде 0,1 М азотной кислоты реакция ионов железа(III) с налидиксовой кислотой была использована для селективного доказательства и определения железа.

Nalidixic acid (*I*, 7-methyl-4-oxo-1-(*N*-ethyl)-1,8-naphthyridine-3-carboxylic acid) and *nor*-nalidixic acid [*II*] (*II*, 7-methyl-4-hydroxy-1,8-naphthyridine-3-carboxylic acid) are poorly soluble in water, while their solubility in basic solvents and in aqueous solutions of bases is fairly high. In solutions they behave like weak acids.



In an acid medium (pH 1) nalidixic acid reacts with Fe(III) ions, with the formation of a yellow colouring. At  $\text{pH} \geq 3$ , a precipitation of red-brown Fe(III) basic salts can be observed. Reaction of other ions are insignificant.

The *nor*-nalidixic acid gives several more reactions. In an acid medium it reacts with the following ions: Fe(III) (red-brown solution), Cu(II) (green-yellow precipitate), Ag(I), Hg(I), and Hg(II) (yellowish precipitates). The coordination of a cation with the agent, which is a weak acid, demonstrates itself in unbuffered media by a release of the corresponding amount of hydrogen ions which can be determined by alkalimetric titration.

## Experimental

### *Chemicals and equipments*

The stock Fe(III) ions solutions were prepared by dissolving solid  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  in 0.1 M-HCl or  $\text{FeNH}_4(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$  in 0.1 M- $\text{HClO}_4$ . The resulting concentrations were 0.1 or 0.01 M. The iron content was determined by chelatometry using pyrocatechol violet [2].

Solutions of nalidixic and *nor*-nalidixic acids with  $10^{-2}$  M concentrations were prepared by dissolving a corresponding amount of the substances in 0.1 M-NaOH.

Both acid-base and coordination reactions were studied in aqueous media, only for the determination of Fe(III) a water-ethanolic medium (40% v/v) was used because of a limited solubility of nalidixic acid. The pH adjustments were accomplished using the solutions of HCl,  $\text{HClO}_4$ , and NaOH with various concentrations; for measurements of the dissociation constants, the Britton-Robinson buffer solutions were used. The ionic strength was adjusted using 1 M-KCl ( $\text{NaClO}_4$ ) up to  $I = 0.1$ . All the chemicals used were anal. grade.

Spectrophotometric measurements were performed using a recording spectrophotometer Specord UV-VIS (Zeiss, Jena) and a spectrophotometer Spektromom 202 (Hungary). A laboratory pH-meter PHK-1 (Mikrotechna, Prague) with a universal cell SEAJ was used for pH measurements. Calculations of the conditional stability constants for *nor*-nalidixic acid were made using a digital computer Minsk 22 (USSR) [7].

### ✧ *Evaluation of experimental data*

Dissociation constants were determined by a common procedure. The composition of complexes of both the acids was studied by the molar ratios method [3], the tangent ratio method [4], and the Job method of continual variations [5]. The first values of the conditional stability constants were calculated from the difference between the Job curve of the quantitative and real reactions at  $X_{\text{max}}$  [6]. For *nor*-nalidixic acid, precise values were obtained from numeric analysis of the concentration curve ( $I$ ), providing that only the complex with a 1 : 1 ratio of components M and L is formed (2-5)

$$A = f(c_M)_{(c_L, \text{pH}=\text{const})}, \quad (1)$$

$$A = \varepsilon[\text{ML}'], \quad (2)$$

$$\beta'_1 = \frac{[\text{ML}']}{[\text{M}'][\text{L}]}, \quad (3)$$

$$c_L = [L'] + [ML'], \quad (4)$$

$$c_M = [M'] + [ML']. \quad (5)$$

From experimental points of the dependence ( $I$ ), the best fitted curve corresponding to the optimum values of  $\beta'_1$  and  $\varepsilon$  was calculated by the least-squares method [7].

## Results and discussion

In a common region of pH, nalidixic acid shows one acid-base equilibrium

$$(\text{p}K_{a1}(\text{HL}/\text{L}^-) 6.12 \pm 0.03)$$

characterized by a dissociation of the proton of the carboxylic group. The dissociation is accompanied by a bathochromic shift of the first long-wave band ( $\lambda_{\text{max}}^{\text{HL}}$  315 nm,  $\lambda_{\text{max}}^{\text{L}^-}$  333 nm).

The *nor*-nalidixic acid exhibits a greater number of acid-base equilibria. The  $\text{H}_2\text{L}$  form has the first long-wave band with maxima at 308 and 319 nm. In strongly acid media (pH  $\sim 0$ ), the absorption maximum of the protonized form can be found at about 341 nm. The corresponding  $\text{p}K_{a0}(\text{H}_3\text{L}^+/\text{H}_2\text{L})$  shows a negative value ( $\sim -0.15$ ). In a mild acid medium, the dissociation of the carboxylic proton occurs, the value of  $\text{p}K_{a1}$  and the changes of absorption maxima ( $\text{p}K_{a1}(\text{H}_2\text{L}/\text{HL}^-) 5.88 \pm 0.01$ ,  $\lambda_{\text{max}}^{\text{HL}^-}$  328 nm) being similar to those of nalidixic acid. The phenolic group is ionized in alkaline medium ( $\text{p}K_{a2}(\text{HL}^-/\text{L}^{2-}) 10.60 \pm 0.03$ ), this dissociation being accompanied by a bathochromic shift of the first long-wave band ( $\lambda_{\text{max}}^{\text{L}^{2-}}$  333 nm).

The complex formation of *nor*-nalidixic acid in the acid medium is manifested by two absorption bands at about 350 and 425 nm. The formation of a complex with the composition ratio of 1 : 1 was proved by the above-mentioned methods. The conditional stability constants were determined by a numerical analysis of the concentration curve ( $I$ ) ( $\log \beta'_1(\text{ML}) 3.77 \pm 0.1$ , pH 1.11). The molar absorption coefficient was found to be  $0.625 \times 10^3$  at  $\lambda = 425$  nm.

The complex of nalidixic acid with Fe(III) ions exhibits similar absorption bands at 350 and 425 nm, however, the reaction course is different. The complex composition, determined by the same methods as in the previous case, corresponds to the formula  $\text{ML}_2$ . The conditional stability constant was calculated from the conjugated points on the concentration curve ( $\log \beta'_2(\text{ML}_2) 8.34$ , pH 1.01). A comparable value of the constant was obtained from the difference between the Job curves of a quantitative and real reactions at  $X_{\text{max}}$  ( $\log \beta'_2(\text{ML}_2) 8.2$ , pH 1.01).

In an acid medium (pH  $\sim 1$ ), nalidixic acid may be used for a selective detection and determination of Fe(III). Because of a limited solubility of the agent, it is convenient to use 40% (v/v) ethanol. The yellow colour of the complex is stable for several hours, the molar absorption coefficient being  $2.6 \times 10^3$  for  $\lambda$  425 nm. The reaction makes it possible to determine 0.12–0.7 mg of Fe in 50 ml of the solution. The relative width of the confidence interval  $\tau$  is 0.7% for 6 parallel determinations and a concentration of Fe 6.7  $\mu\text{g/ml}$ . The presence of common anions ( $\text{NO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{AsO}_3^{3-}$ ,  $\text{AsO}_4^{3-}$ ,  $\text{Br}^-$ ,  $\text{ClO}_4^-$ ,  $\text{NO}_2^-$ ,  $\text{SiO}_3^{2-}$ ,  $\text{SO}_4^{2-}$ ,  $\text{IO}_3^-$ ) and alkali metals does not interfere.

The determination may be carried out in the presence of more than fiftyfold excess of  $\text{NH}_4^+$ , Mg(II), Ca(II), thirtyfold excess of Co(II), Cu(II), Zn(II), Cd(II), Mn(II), Hg(I), Ag(I), tenfold excess of Hg(II), La(III), Y(III), Ce(III), and fivefold excess of Th(IV) and Fe(II).

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