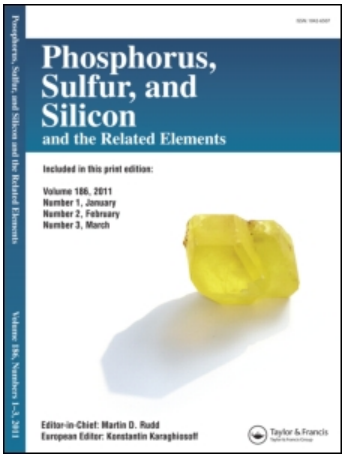

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PROTONATION AND METAL COMPLEX FORMATION OF PHOSPHORUS CONTAINING ACIDS AND BASES

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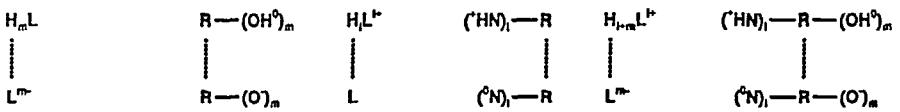
Biorelevant acylphosphonic acids, phosphonocarboxylic acids, aminophosphonic acids and corresponding phosphinic acids give rise to interesting protonation and metal complex formation equilibria. Macroscopic stability constants are obtained by high precision PC-guided titration followed by iterative data evaluation. Additional informations on dynamically averaged structures of species involved in macroscopic equilibria, e. g. ion specific chemical shifts and coupling constants, are accessible via NMR-controlled titrations.

To understand these phenomena we will classify some model systems into 3 classes as shown below:

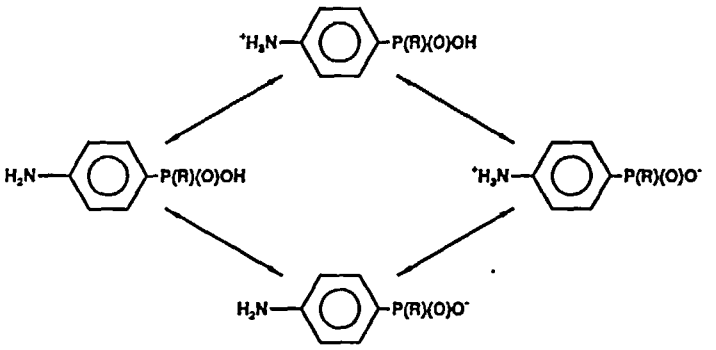
No.	Compound	Acid Type
1	$CH_3C(O)OH$	1 HL
2	$(CH_3)_2P(O)OH$	1 HL
3	$CH_3P(O)(OH)_2$	1 H_2L
4	$HO(O)(CH_3)PCH_2CH_2C(O)OH$	1 H_2L
5	$(HO)_2(O)PCH_2CH_2C(O)OH$	1 H_3L
6	NH_4^+	2 HL^+
7	$^+H_3NCH_2CH_2NH_3^+$	2 H_2L^{2+}
8	$^+H_2(CH_2CH_3)NCH_2P(CH_3)(O)OH$	3 H_2L^+
9	$^+H_3NCH(C_2H_5)P(O)(OH)_2$	3 H_3L^+
10	$^+H_3NCH_2CH_2P(O)(OH)_2$	3 H_3L^+
11	$^+H_3NC_6H_4P(O)(OH)_2$	3 H_3L^+



Type 1 Type 2 Type 3

The protolytic equilibria of those acids involve the following species: Type 1: neutral acids ↔ anionic bases, Type 2: cationic acids ↔ neutral bases, Type 3: cationic acids ↔ anionic bases. Parallel observations of pH and NMR spectra of proto-

ves pH=f(V_b) or pH=f(τ), and the two-dimensionally correlated diagrams δ=f(V_b), δ=f(τ), δ=f(pH) obtained as stacked or contour plots. Technical details to hardware and software setup for NMR controlled titrations are given in [1]. Since the potentiometric measurement using a glass electrode and the NMR method as well is slow with respect to proton transfer in protolytic equilibria in general only the macroscopic dissociation constants are obtained from NMR controlled titrations. This is discussed together with underlying theory for model systems given in Table 1 above. For certain limiting conditions microscopic dissociation constants are accessible This is shown for compounds No. **4**, **8** and **9**. Recent interests are directed towards microscopic aspects of protolytic equilibria, e. g. such as:



Since the biological activities of these organophosphorus compounds and related structures will be influenced by the population of individual species shown in both schemes above it is imperative to inspect the microscopic equilibria by suitable methods. In addition to NMR techniques in favourable cases UV/VIS-controlled titrations (PHOTO_T) may lead to microscopic stability constants[2].

The formation of metal complexes is observed. Practical examples will involve aminophosphonic acids, e. g. Ciliatin **10**, and acylphosphonates obtained from the E. Breuer group in Jerusalem and FOSCARNET from K. Kellner, Halle.

Other practical applications of NMR controlled titrations are involved with the identification of reaction mixtures. As a typical problem from industrial chemistry[3] the five-basic 1-phosphono-propane-1,2,3-tricarboxylic acid is used:

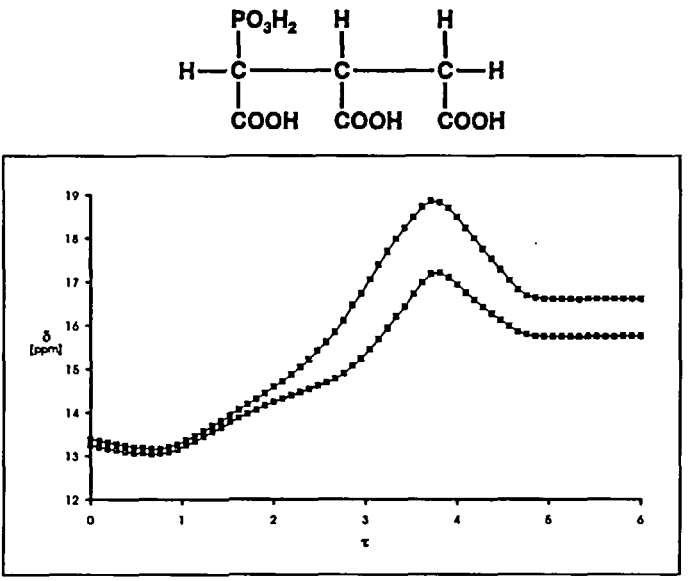


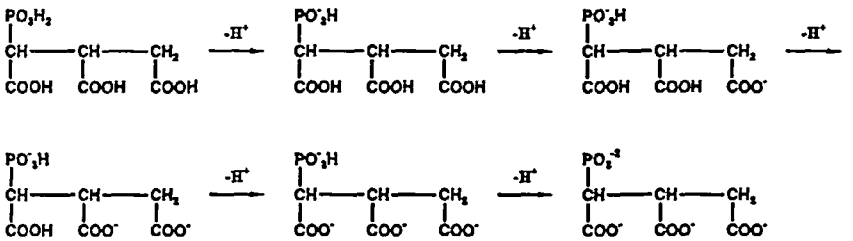
Figure 1: 81 MHz $^{31}P\{1H\}$-NMR controlled titration of H_5PPTC vs. NaOH. x-axis: degree of titration τ, x-min = 0, x-max = 6; y-axis: chemical shift δ_P [ppm], y-min = 12, y-max = 19.

Since carbon atoms C1 and C2 in PPTC are chiral, two specific forms (threo and erythro) are expected. Figure 1 clearly shows 2 phosphorus signals, but a stereospecific assignment is possible only by involvement of high resolution ^1H- and ^{13}C-NMR studies [2]. Analysis of data from NMR controlled titration yielded dissociation constants and ion specific chemical shifts for each form separately.

Parameter	Form 1	Form 2	Parameter	Form 1	Form 2
pK_S1:	1.36	1.18	$\delta p(H_5L)$:	15.99	16.88
pK_S2:	3.71	3.21	$\delta p(H_4L^-)$:	12.93	12.83
pK_S3:	4.95	4.26	$\delta pH_3L^{-2})$:	14.09	13.39
pK_S4:	6.55	6.77	$\delta p(H_2L^{-3})$:	15.76	14.61
pK_S5:	9.47	9.34	$\delta p(HL^{-4})$:	19.04	17.41
			$\delta p(L^{-5})$:	16.58	15.74

Table 2: Dissociation constants and ion specific chemical shifts δp [ppm] for the two epimeric forms of PPTC.

The most likely deprotonation sequence of PPTC is described in the following scheme:



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References

1 a) G. Hägele. Review in "Phosphorus-^{31}P-NMR Spectral Properties in Compound Characterization and Structural Analysis". (Edit. L. D. Quin und J. G. Verkade). VCh **1994.**

b) J. Ollig and G. Hägele. Computers Chem. **19,** 287 (1995)

2 a) G. Hägele, H.-J. Majer und F. Macco. GIT, **9/92,** 922

b) C. Arendt and G. Hägele. Computers Chem. **19,** 269 (1995)

3 H. Blum, G. Hägele, H. W. Kropp et al.; to be published in 1996