Synthesis and Spectroscopy of Phosphonate Derivatives of Uracil and Thymine. X-Ray Crystal Structure of Diethyl 6-Uracilmethylphosphonate

Justyn Ochocki*‡, Andrea Erxleben and Bernhard Lippert

Fachbereich Chemie, Universität Dortmund, D44221 Dortmund, Germany

Received March 18, 1997

A new class of phosphonate ligands, derived from uracil and thymine was designed, prepared and characterised. Dimethyl (**4**, **7**) and diethyl (**5**, **8**) uracilmethylphosphonates have been prepared by the reaction of chloromethyluracil isomers **2** and **3** with trimethyl phosphite and triethyl phosphite, respectively. The corresponding free acids, 5-uracilmethylphosphonic acid **6** and 6-uracilmethylphosphonic acid **9**, have also been isolated. The structure of the compounds has been assigned by nmr spectroscopy and, in the case of **8**, confirmed by X-ray analysis.

J. Heterocyclic Chem., **34**, 1179 (1997).

The nucleobase uracil is a fundamental constituent of RNA. Derivatives with substituents at the 5- or 6-positions are of considerable interest due to their therapeutic potential as antiviral [1] or antitumor agents [2]. Very recently the potential relevance of 5-substituted uracils in transition of the RNA to the DNA/protein world has been discussed [3]. Probably the most important representative uracil compounds is 5-fluorouracil, used alone or in combination with other anticancer agents. In medicine, 5-fluorouracil is well known as one of the most effective cytotoxic agents in the treatment of various solid tumors/carcinomas of the gastro-intestinal tract, breast, head and neck [4,5]. An example of combination therapy with two kinds of antitumor drugs is the administration of 5-fluorouracil with Cisplatin [6]. The ligating properties of uracil and its derivatives toward *cis*-$[Pt(NH_3)_2(H_2O)_2]^{2+}$ have been intensively studied [7] following reports on high antitumor activity of complexes ("platinum pyrimidine blues") obtained in these reactions [8].

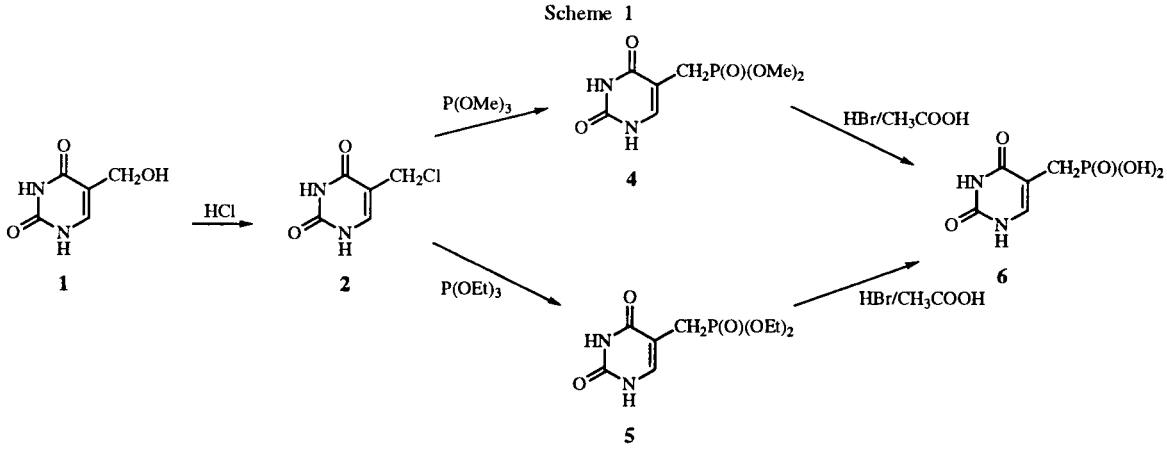
Phosphonate esters of heterocyclic systems have recently attracted interest due to their high reactivity toward transition metals ions and their biological activity [9], and, platinum(II) complexes of phosphonate ligands because of their significant antitumor activity [10,11].

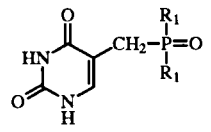
This biological relevance prompted us to design and synthesize phosphonate derivatives of uracil and thymine for further pharmacological tests. In the preliminary screening tests, compounds **4** and **7** as individual agents and in combination with cisplatin, were found to prolong survival time in mice with lymphoid leukemia L-1210 [12]. In continuation of our previous work on the synthesis and the structure of uracil system as well as on phosphonate ligands with a heterocyclic ring we now report on the synthesis and spectroscopy of the phosphonate ligands, derived from uracil and thymine, as well as the X-ray structure of a representative compound, *viz.* diethyl 6-uracilmethylphosphonate **8**.

Results and Discussion.

The general route leading to 5- and 6-uracilmethylphosphonate derivatives is depicted in Scheme 1. The condensation of **2** and **3** with trimethyl or triethyl phosphite affords the corresponding uracilmethylphosphonate esters **4**, **7** and **5**, **8**. Alternatively, these compounds were prepared by the reaction of dimethyl or diethyl sodium phosphite with the corresponding chloromethyluracil. For

Scheme 1

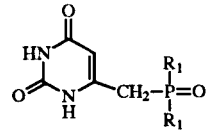




R_1 = OH, 5-uracilmethylphosphonic acid, **6**

R_1 = OCH_3, dimethyl 5-uracilmethylphosphonate, **4**

R_1 = OC_2H_5, diethyl 5-uracilmethylphosphonate, **5**



R_1 = OH, 6-uracilmethylphosphonic acid, **9**

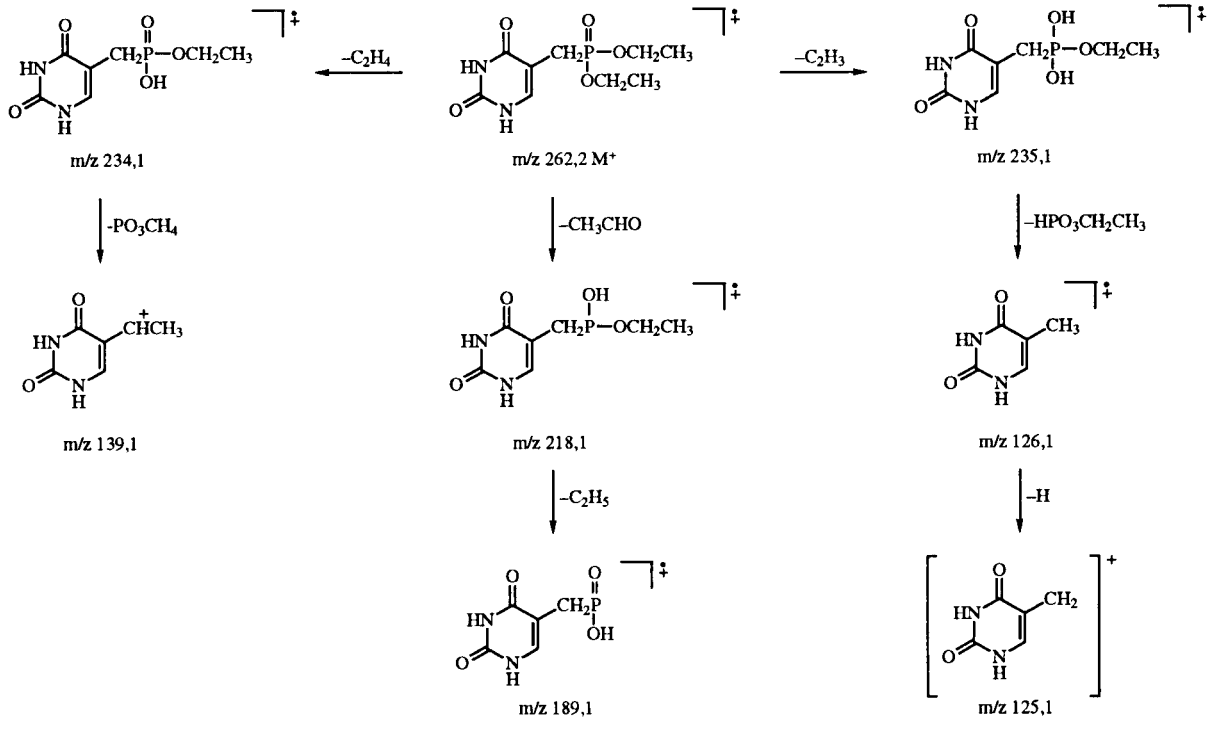
R_1 = OCH_3, dimethyl 6-uracilmethylphosphonate, **7**

R_1 = OC_2H_5, diethyl 6-uracilmethylphosphonate, **8**

Figure 1. Schematic structures of the uracil phosphonate derivatives.

example 5-chloromethyluracil on reaction with diethyl sodium phosphite yields diethyl 5-uracilmethylphosphonate. The structures and their respective names of uracil derivatives are given in Figure 1. Dimethyl 5-uracilmethylphosphonate (**4**) and diethyl 5-uracilmethylphosphonate (**5**) were prepared according to Scheme 1. By analogy, dimethyl 6-uracilmethylphosphonate (**7**) and diethyl 6-uracilmethylphosphonate (**8**) also have been synthesized. The first stage in the synthesis of dimethyl 5-uracilmethylphosphonate (**4**) is to prepare 5-chloromethyluracil (**2**) by the reaction of 5-hydroxymethyluracil (**1**) with concentrated hydrochloric acid (**1**→**2**). In the ^1H nmr spectrum of 5-chloromethyluracil (**2**) a singlet of two methylene group protons with a chemical shift of δ = 4.55 ppm was observed. A proton doublet with chemical shift δ = 7.9 ppm, $^3J_{HH}$ = 6.1 Hz was attributed to the C_6 proton of the aromatic ring. Two singlets with chemical shifts of δ = 11.15 ppm and δ = 11.4 ppm originate from the protons of the two NH groups. Dimethyl 5-uracilmethylphosphonate (**4**) and diethyl 5-uracilmethylphosphonate (**5**) were synthesized *via* the 5-chloromethyluracil condensation with trimethyl phosphite and triethyl phosphite, respectively. In order to increase the yield of the reaction, an excess of phosphite was used. The analysis of the ^1H nmr spectra reveals the two ester groups as being chemically equivalent. The signals of six protons from two methyl groups result in a doublet with a chemical shift of δ = 3.61 ppm, $^2J_{HP}$ = 10.8 Hz, for **4** and in a triplet, δ = 1.33 ppm, $^3J_{HH}$ = 7.0 Hz, for **5**. Four protons from two methylene groups of the ester chain give a doublet of quartets with δ = 4.07 ppm and $^3J_{HH}$ = 7.0 Hz and $^2J_{HP}$ = 7.0 Hz for **5**. The two protons of the -CH_2P methylene group bound to the uracil ring give rise to a doublet with chemical shift δ = 2.83, $^2J_{HP}$ = 20.12 Hz for **4** and δ = 2.88, $^2J_{HP}$ = 20.0 Hz for **5**, respectively, whereas a doublet with δ = 7.33 ppm and $^3J_{HH}$ = 1.68 Hz for **4** and δ = 7.33 ppm and $^3J_{HH}$ = 1.68 Hz for **5**, is attributed to the C(6) proton of the aromatic system. The ^1H nmr spectrum revealed two imino proton resonances at δ = 10.84 for **4**, δ = 10.92 ppm for **5**, and δ = 11.12 for **4**, δ = 11.29 ppm for

Scheme 2. Fragmentation Pathway for Diethyl 5-Uracilmethylphosphonate (**5**)



5. Their assignment to N(1)H and N(3)H, respectively, was aided by the 2D-COSY crosspeaks between the N(1)H proton and C(6)H of the uracil ring. Crosspeaks were also observed for OCH_3 protons of the ester chain and the protons of methylene group CH_2-P bound with the uracil system. Additional support for the structure of the compounds comes from mass spectrometry. Interpretation of the fragmentation pathway revealed the presence of signals characteristic of esters and phosphonate acids. In the mass spectrum of **5**, apart from molecular ion M^+ peak of m/z = 234, the peaks of fragmentation ions of M^+ - 109 of m/z 125, and M^+ - 125 of m/z 109, which are characteristic of this class of compounds were observed. On the basis of the results in the mass spectrum the following fragmentation pathway can be proposed (Scheme 2).

The ir spectrum displays a very intensive band at 1248 cm^{-1} characteristic of the phosphonate group (P=O) [13]. Also, the bands at 1040 and 1080 cm^{-1}, corresponding to a (POC) group, and two bands at 1680 cm^{-1}, corresponding to a C=O group, can be seen. The bands at 2800 cm^{-1} and 3200 cm^{-1} are attributed to two NH stretching modes. Phosphorylation of 6-chloromethyluracil (**3**) with trimethyl phosphite (**3**→**7**) and with triethyl phosphite (**3**→**8**) was carried out following the procedure that was described for **4** and **5**. 6-Substituted uracils were isolated in good yields. In order to unequivocally define the structure of **7** and **8**, ^1H-^1H COSY experiments were performed and analyzed. They clearly demonstrate the correlation between C(5) protons and N(1) and N(3) of the heterocyclic ring.The signal at 10.83 ppm for **7** and 10.91 for **8**, respectively is attributed to the N(1) proton, whereas the signal at 11.04 ppm for **7** and 11.14 for **8** is assigned ppm to the N(3) proton of the uracil ring. The structure of **8** has been determined by single-crystal X-ray diffraction. A view of the diethyl 6-uracilmethylphosphonate (**8**), together with the atomic labelling scheme, is given in Figure 2. The crystal data and details of the structure refinement are given in Table 1,

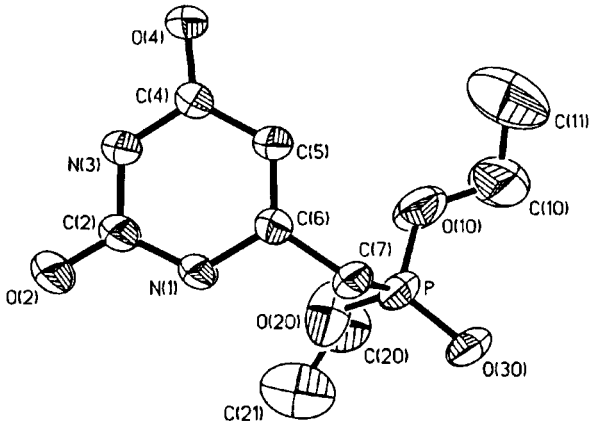


Figure 2. Molecular structure and atom numbering of diethyl 6-uracilmethylphosphonate **8**.

Table 1

Crystallographic Data for Diethyl 6-Uracilmethylphosphonate **8**

Crystal data	
Formula	$C_9H_{15}N_2O_5P$
Crystal system	orthorhombic
Space group	$P2_12_12_1$
a,Å	7.322(3)
b,Å	12.735(8)
c,Å	1 4.059(6)
V, Å^3	1310.9(11)
Z	4
Formula weight	262.202
Density (calc.)	1.329 g/cm^3
Crystal size (mm)	0.512 x 0.128 x 0.160
Absorption coefficient	2.134 mm^{-1}
F(000)	552.0
Data collection	
Radiation	MoKα (λ = 0.71073 Å)
Temperature (K)	293
2θ range	2 to 50°
Scan range (ω)	1.20° plus Kα-separation
Index ranges	$-8\le h\le 0$, $-15\le k\le 0$, $-16\le l\le 0$
Reflections collected	1383
Independent reflections	1365
Observed reflections	959 ($F > 4\sigma(F)$)
Absorption correction	ψ-scans
Weighting scheme	$w^{-1} = \sigma^2(F_o^2) + (0.1124 * P)^2$ $P = (F_o^2 + 2F_C^2) / 3$
Refinement	
Number of parameters refined	154
Final R indices (obs. data)	$R_1 = 5.8\%$, $wR_2 = 16.0\%$ [a]
R indices (all data)	$R_1 = 8.0\%$, $wR_2 = 17.8\%$ [a]
Goodness-of-fit (all data)	0.965
Largest and mean Δ/σ	< 0.001/< 0.001/

[a] $R_1 = \Sigma||F_o| - |F_c|| / \Sigma|F_o|$; $wR_2 = (\Sigma w(F_o^2-F_c^2)^2 / \Sigma w(F_o^2)^2)^{0.5}$

Table 2

Atomic Coordinates (x 10^4) and Equivalent Isotropic Displacement Parameters (Å^2 x 10^3) for **8**

	x	y	z	U(eq)*
P	2442(2)	3507(1)	3956(1)	58(1)
O(30)	1204(6)	2589(3)	-3921(3)	70(1)
N(3)	7073(5)	6211(3)	-5346(3)	47(1)
O(2)	9009(5)	4882(3)	-5777(4)	77(2)
N(1)	6048(6)	4471(3)	-5454(3)	46(1)
C(6)	4289(6)	4799(4)	-5227(4)	41(1)
C(2)	7480(8)	5165(4)	-5539(4)	52(1)
C(5)	3917(7)	5825(4)	-5076(4)	46(1)
O(4)	5189(5)	7541(3)	-4963(4)	66(1)
C(4)	5361(6)	6583(4)	-5121(4)	45(1)
O(20)	4393(7)	3329(4)	-3531(4)	91(2)
O(10)	1681(7)	4467(3)	-3410(4)	96(2)
C(10)	193(14)	4566(8)	3096(9)	142(5)
C(7)	2916(7)	3931(3)	-5166(4)	47(1)
C(20)	4616(13)	2980(7)	-2537(6)	101(3)
C(21)	6121(18)	2163(8)	-2521(6)	133(4)
C(11)	-853(18)	5647(9)	-3015(7)	148(4)

*U(eq) is defined as one third of the trace of the orthogonalized Uij tensor.

atomic coordinates in Table 2, and selected bond distances and angles in Table 3. An unambiguous crystallographic differentiation of N(1) and C(5) is not possible due to the pseudo-twofold axis through N(3) and C(6), but the assignment of N(1) and C(5) seems reasonable on the basis of possible hydrogen bonding interactions in the crystal lattice. Thus N(1) and O(30) of neighboring molecules (x+1/2; -y+1/2; z-1) have a short contact of 2.770 (6) Å which is consistent with a N(1)H···O(30) hydrogen bond. In contrast, the separation between C(5) and O(4) of adjacent molecules (x-1/2; -y + 1/2 ;-z - 1) is clearly much longer, 3.433(6) Å, reflecting the expected weaker interaction between the aromatic proton H5 and the acceptor O(4). The bond lengths and angles in the uracil ring are in agreement with the available data on X-ray diffraction studies on this heterocyclic system [14, 15, 16].

Table 3

Bond Lengths (Å) and Angles (deg) for **8**

P-O(30)	1.479(4)		
P-O(10)	1.548(5)		
P-O(20)	1.565(5)		
P-C(7)	1.818(6)		
N(3)-C(4)	1.377(6)		
N(3)-C(2)	1.392(6)		
O(2)-C(2)	1.223(7)		
N(1)-C(2)	1.376(7)		
N(1)-C(6)	1.391(6)		
C(6)-C(5)	1.352(6)		
C(6)-C(7)	1.496(6)		
C(5)-C(4)	1.433(7)		
O(4)-C(4)	1.247(6)		
O(20)-C(20)	1.475(10)		
O(10)-C(10)	1.447(10)		
C(10)-C(11)	1.463(14)		
C(20)-C(21)	1.516(13)		
O(30)-P-O(10)	112.8(3)	O(2)-C(2)-N(1)	122.2(4)
O(30)-P-O(20)	115.6(3)	O(2)-C(2)-N(3)	122.1(5)
O(10)-P-O(20)	104.7(3)	N(1)-C(2)-N(3)	115.8(5)
O(30)-P-C(7)	112.5(2)	C(6)-C(5)-C(4)	119.7(5)
O(10)-P-C(7)	107.4(3)	O(4)-C(4)-N(3)	118.0(4)
O(20)-P-C(7)	103.0(3)	O(4)-C(4)-C(5)	125.3(5)
C(4)-N(3)-C(2)	124.6(4)	N(3)-C(4)-C(5)	116.8(4)
C(2)-N(1)-C(6)	122.2(4)	C(20)-O(20)-P	120.4(5)
C(5)-C(6)-N(1)	120.8(4)	C(10)-O(10)-P	124.1(5)
C(5)-C(6)-C(7)	124.8(4)	O(10)-C(10)-C(11)	114.8(9)
N(1)-C(6)-C(7)	114.4(4)	C(6)-C(7)-P	113.7(3)
		O(20)-C(20)-C(21)	107.5(7)

Uracilmethylphosphonic acids, **6** and **9** were synthesised in one step by the hydrolysis of the corresponding esters with hydrobromic acid in acetic acid (**4,5**→**6** and **7,8**→**9**). Formation of these acids is depicted schematically in Scheme 1. All acids were isolated as thermally stable, colourless, crystalline high melting solids. The structures of **6** and **9** were confirmed by the nmr spectra. The ^{1}H nmr spectra of **6** and **9** show two signals at 10.85 and 11.20 and 10.91 and 11.14 ppm, attributable to the N(1) and N(3) protons, respectively, of the uracil ring. The signal which appears as doublet at 2.67 and 2.85 due to ^{31}P-^{1}H coupling, is assigned to the CH_2-P protons. The other resonances in the aromatic region at 8.4 and 9.9 are assigned to the hydroxyl groups of the phosphoric function for **6** and **9**, respectively.

In conclusion, we have developed a concise and convenient route for the synthesis of the phosphonate derivatives of uracil and thymine. This is of interest in view of the biological significance of uracil nucleobases in general and the antitumor activity of two of these compounds in particular [12]. Activity of these substituted uracils in combination with Cisplatin includes a possibility for a direct interaction of these two agents, hence complex formation. After all, for "platinum pyrimidine blues" a number of biological effects other than antitumor activity has been reported [18]. We plan to further study this aspect by synthesizing, characterizing and testing platinum (II) complexes of uracilmethylphosphonates.

EXPERIMENTAL

All melting points were taken on a capillary melting point apparatus and are uncorrected. The ^{1}H and ^{13}C nmr spectra were recorded on a Bruker MS L-300 spectrometer in dimethyl sulfoxide-d_6 (DMSO-d_6). Chemical shifts for ^{1}H and ^{13}C are reported in parts per million (ppm) and are referenced to tetramethylsilane. 2D nmr spectra (^{1}H,^{1}H COSY) were recorded according to standard procedures: SF 300.13 MHz, SI 2048 K points in F2, SI 1024 in F1, pulse 90° -22V, relaxation delay 2S. The ^{31}P nmr spectra were measured on a Bruker AC-200 using 80% H_3PO_4 as external standard. Mass spectra were obtained with a LKB 2091 mass specrometer (electron impact, 70 eV). The ir spectra were recorded on a Perkin-Elmer PE 380 spectrophotometer using samples in potassium bromide discs.

Materials. All commercial reagents were ACS reagent grade and used without futher purification. 5-chloromethyluracil **2** was prepared by chlorination of 5-hydroxymethyluracil with hydrochloric acid according to the literature method [2]. Di- and trimethyl phosphite and di- and triethyl phosphite were distilled immediately prior to use.

General Phosphorylation Procedure for the Synthesis of 5- and 6-Substituted Uracils **4-9** from 5-Chloromethyluracil (**2**) or 6-Chloromethyluracil (**3**).

Method (a).

A mixture of **2** or **3** and trimethyl phosphite or triethyl phosphite was refluxed until a transparent solution had formed. The solution was then allowed to cool to room temperature followed by separation of the white crystalline product. The product was filtered, washed with ethanol and dried *in vacuo*.

Method (b).

To a solution of dimethyl phosphite or diethyl phosphite in hexane elemental sodium was added portionwise with stirring. The mixture was refluxed until sodium was dissolved. To the resulting mixture a solution of **2** or **3** in hexane was added drop-

wise. The resulting mixture was stirred under reflux for 6 hours. The solvent was evaporated *in vacuo* yielding a white product, which was washed with ethanol and dried *in vacuo*.

Dimethyl 5-Uracilmethylphosphonate (**4**).

Following the general procedure (a), **2** (1.5 g, 9.3 mmoles) was phosphorylated with trimethyl phosphite (25 ml, 19 mmoles) to afford 1.9 g (87%) of **4** as a white solid, mp 171-173°; ^{1}H nmr (DMSO-d_6, 200 MHZ): δ 2.83 (d, 2H, $^2J_{HP}$ = 12.0, CH_2-P), 3.61 (d, 6H, $^3J_{HP}$ = 10.8, $2CH_3$), 7.33 (d, 1H, $^3J_{HH}$ = 1.68, aryl C(6)), 10.84 (s, 1H, N(1), 11.12 (s, 1H, N(3)H); ^{31}P nmr (deuteriochloroform): 30.33; ir (potassium bromide): ν 1248 (P=O), 1040, 1080 (PO-C), 2800, 3200 (NH), 1680, 1740 (C=O) cm^{-1}.

Anal. Calcd. for $C_7H_{11}N_2PO_5$: C, 35.91; N, 11.96; H, 4.74; P, 13.23. Found: C, 36.02; N, 11.70; H, 4.89; P, 12.90.

Dimethyl 6-Uracilmethylphosphonate (**7**).

This compound was obtained as colorless needles from **3** in 58% yield, mp 228-230°; ir (potassium bromide): δ 1215 (P=O), 1660, 1720 (C=O), 1030, 1070, 970 (POC), 2800, 3200 (NH) cm^{-1}; ^{1}H nmr (DMSO-d_6, 200 MHz): δ 3.08 (d, 2H, $^2J_{HP}$ = 22.4, $4CH_2P$), 3.68 (d, 6H, $^3J_{HP}$ = 11-05, $2CH_3$), 5.41 (d, 1H, $^3J_{HH}$ = 3.87, aryl C_5-H), 10.83 (s, 1H, N(1)), 11.04 (s, 1H, N(3)); ^{31}P nmr: (deuteriochloroform): 25.79.

Anal. Calcd. for $C_7H_{11}N_2PO_5$: C, 35.91; H, 4.74; N, 11.96; P, 13.23. Found: C, 35.36; H, 4.93; N, 11.10; P, 13.44

Diethyl 5-uracilmethylphosphonate (**5**).

Compound **5** was obtained in 89% yield from **2**, mp 168-170° (ethanol); ir: ν 1248 (P=O), 1012-1080 (POC), 1708 (C=O), 2900-3400 (NH) cm^{-1}; ^{1}H nmr: (DMSO-d_6): δ 1.33 (t, 6H, $2CH_3$), 2.88 (d, 2H, CH_2P), 4.07 (dq, 4H, $2POCH_2$), 7.4 (d, 1H, aryl H-C(6), 10.92 (s, 1H, N(1)H), 11.29 (s, 1H, N(3)H); ^{31}P nmr (deuteriochloroform): 27.79; ms: m/z (%): M+ 262.1 (28.29), 234.1 (14.52), 235.1 (2.17), 126.1 (100), 139.1 (16.70), 218.1 (2.46), 189.1 (13.73), 125.1 (32.28).

Anal. Calcd. for $C_9H_{15}N_2PO_5$; C, 41.18; H, 5.72; N, 10.67; P, 11.82. Found: C, 41.58; H, 5.80; N, 10.69; P, 12.00.

Diethyl 6-Uracilmethylphosphonate (**8**).

This compound was synthesised in 92% yield from **2**, mp 210-215° (methanol); ir: ν 1208 (P=O), 1668, 1712 (C=O), 1000-1080, 960 (POC), 2800-3300 (NH) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 1.32 (t, 6H, $2CH_3$), 3.14 (d, 2H, CH_2P), 4.1 (dq, 4H, $2POCH_2$), 5.49 (d, 1H, aryl C(6)), 10.91 (s, 1H, N(1)H), 11.14 (s, 1H, N(3)H); ^{31}P nmr (deuteriochloroform): 23.20; ms: m/z (%) M+ 262.2 (23.5), 126.2 (100), 234 (79), 235 (11), 218 (18), 139 (53), 125 (64), 189 (54).

Anal. Calcd. for $C_9H_{15}N_2P_1O_5$: C, 41.18; H, 5.72; N, 10.67; P, 11.82. Found: C, 41.17; H, 5.84; N, 10.68; P, 11.56.

General Procedure for the Synthesis of 5- and 6-Substituted Uracil Acids.

A solution of ester **4**, **5**, **7**, **8** in an appropriate volume of hydrobromic acid (33%)-acetic acid was stirred at 25° under a nitrogen atmosphere for 72 hours. The resulting precipitate was filtered, washed with water and dried.

5-Uracilmethylphosphonic acid (**6**).

Following the general procedure **6** was obtained in 58% yield from **4**, and in 90% yield from **5**, mp 360-365° (ethanol-water); ir: ν 1240 (P=O), 1000-1080 (PO-C), 960 (POC), 1674-1740 (C=O), 2300-3400 (P-O-H), 2300-3400 (NH) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 2.67 (d, 2H, J_{PCH2} = 20.0, CH_2P), 7.38 (d, 1H, J_{HH} = 3.13, aryl H-C6), 8.4 (s, 2H, 20H), 10.85 (s, 1H, N(1)H), 11.20 (s, 1H, N(3)H); ^{31}P nmr (deuteriochloroform): 22.71.

Anal. Calcd. for $C_5H_7N_2PO_5$: C, 29.12; H, 3.39; N, 13.59; P, 15.04. Found: C, 29.10; N, 13.45; H, 4.01; P, 14.96.

6-Uracylomethylphosphonic Acid (**9**).

This compound was prepared, as described under the general procedure from **7** (77%) and **8** (87%), mp 288-291°(ethanol-water); ir: ν 1240 (P=O), 1660, 1720 (C=O), 1200 (PO-C), 950 (P-OC), 2800-3200 (P-O-H), 2800-3200 (NH) cm^{-1}; ^{1}H nmr (DMSO-d_6): δ 2.85 (d, 2H, $^3J_{HH}$ = 7.0, CH_2P), 5.47 (d, 1H, $^3J_{HH}$ = 3.09, C(5), 9.9 (s, 2H, 2OH), 10.79 (s, 1H, N(1)H), 11.04 (s, 1H, N(3)H); ^{31}P nmr (deuteriochloroform): 17.43.

Anal. Calcd. for $C_5H_7N_2PO_5$: C, 29.12; N, 13.59; H, 3.39; P, 15.04. Found: C, 29.11; N, 13.61; H, 4.03; P, 15.00.

X-Ray Crystal Structure Analysis of **8**.

X-ray data were collected on a Nicolet R3m/V single crystal diffractometer using graphite-monochromated Mo-Kα radiation (λ = 0.71073 Å). Unit cell parameters were obtained from least-squares fit of 25 randomly selected reflections in the range $14.8 \leq 2\theta \leq 29.1°$. Intensity data were collected at room temperature at variable scan up to $2\theta = 50°$ (w/2θ-scan). An empirical absorption correction *via* Ψ-scans was applied. No correction was made for extinction. The structure was solved by convenient Patterson and Fourier methods and refined on F^2 by full-matrix least squares using the SHELXTL PLUS and SHELX-93 systems of crystallographic computer programs [17].

Acknowledgements.

J.O. gratefully acknowledges a grant from the Deutscher Akademischer Austauschdienst (DAAD) and financial support from the Tempus Programme-Individual Mobility Grant IMG-94-PL-2044.

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* Author to whom correspondence should be addressed.

‡ Present address: Institute of Chemistry, Medical University, 90-151 Lodz, Poland.

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