for $PtCl_2Gu(H_2O)_3$ (II) $\nu = 278$ nm, $\epsilon = 9200$ l mol^{-1} cm^{-1}.

The $PtCl_2L(H_2O)_n$ complexes have a *cis*-structure as shown by the characteristic IR spectral bands corresponding to the Pt–Cl stretching vibrations at 320 and 338 cm^{-1} and the formation of a $Pt(thio)_4Cl_2$ complex by the reaction with thiourea, specific to *cis*-compounds. IR spectroscopic and thermogravimetric data have revealed that $PtCl_2L(H_2O)_3$ complexes contain H_2O molecules of different types: (I) - only crystal H_2O, (II) - two crystal H_2O molecules and a molecule of coordinated H_2O. The dehydrated complexes were found not to dissolve in known solvents, strong acids and alkalis. The IR spectra of $PtCl_2L(H_2O)_n$ with different n and the complexes with deuterated L at 1500–1700 and 3100–3500 cm^{-1} (vaseline oil) indicate that both bases interact with Pt^+ ions only *via* the purine heterocyclic nitrogen atoms while the Ad and Gu exocyclic NH_2 groups and the GuCO group are not involved in the coordination.

The NMR spectra of the solutions of the complexes obtained and their deuterated derivatives in DMSO-d_6 have permitted us to suggest that Ad in these complexes acts as a bridge ligand: two Pt(II) atoms add simultaneously to two Ad molecules. All Ad heterocyclic atoms seem to contribute to the formation of the bond with Pt(II) to give a mixture of coordination isomers which gives a complicated picture of the NMR spectra of (I). In (II) Gu acts as a monodentate ligand that interacts with a Pt^+ ion in a keto-form. The Pt(II) atom adds to Gu *via* N7. The GuCO group with a H_2O coordinated molecule forms an intramolecular hydrogen bond.

Biological tests with animals indicate that (I) has moderate antitumour activity, while (II) displays well-defined anti-cancer properties. Both complexes are practically non-toxic.

T10

Hydroxoaquo(3,3′,3″-triaminotripropylamine)cobalt-(III) Ion. A Highly Effective Reagent for Promoting the Hydrolysis of Phosphate Species

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In earlier work we demonstrated the effectiveness of $tn_2Co^{III}(aq)$ in promoting the hydrolysis of phosphate esters [1] and polyphosphates [2–4] [tn = $H_2N(CH_2)_3NH_2$; (aq) = $(OH_2)_2$, $(OH)(OH_2)$ or $(OH)_2$ depending on pH; charges omitted]. Such studies can provide insight into possible roles for metal centers in biological phosphoryl transfer. Under appropriate conditions $tn_2Co^{III}(aq)$ produces, on direct addition to phosphate species, accelerations in hydrolysis of up to $\sim 10^5$.

Using the tripodal ligand trpn [=$N(CH_2CH_2CH_2NH_2)_3$] we have now prepared $trpnCo^{III}(aq)$; this reagent is significantly more effective than $tn_2Co^{III}(aq)$ in promoting hydrolysis of phosphate esters and polyphosphates. Here we compare the reactivities of $trpnCo^{III}(aq)$ and $tn_2Co^{III}(aq)$ towards adenosine 5′-diphosphate (ADP), bis(2,4-dinitrophenyl) phosphate [$(2,4\text{-DNP})_2P$], and 2,4-dinitrophenyl phosphate [2,4-DNPP] [5].

For hydrolysis studies on ADP (20 °C) the N_4Co^{III}ADP 1:1 complex was pre-formed at pH 4.0 prior to addition of further $N_4Co^{III}(aq)$ and pH adjustment to 7.0; reaction was followed by ^{31}P NMR analysis of solutions quenched with NaOH [3, 4]. Hydrolysis studies on $(2,4\text{-DNP})_2P$ and 2,4-DNPP were at 25 °C ($\mu = 0.50$ *M*) with direct mixing of ester and $N_4Co^{III}(aq)$ solutions; reaction was followed spectrophotometrically from production of 2,4-dinitrophenolate.

Table I compares rates for hydrolysis of ADP to AMP and P_i for the two cobalt reagents. In both cases the 1:1 complex is formed almost quantitatively and is of low reactivity, while excess $N_4Co^{III}(aq)$ leads to marked increases in rate. The most noticeable new feature is the much higher reactivity observed for $trpnCo^{III}(aq)$ compared to $tn_2Co^{III}(aq)$. At the highest ratio studied (8:1) the half-life for the trpn system is <1 min, which corresponds to an acceleration over the unpromoted reaction of $>1 \times 10^6$ [7].

TABLE I. ADP Hydrolysis Promoted by $N_4Co^{III}(aq)$[a].

Co/ADP	$k \times 10^4$ (sec^{-1})		k_{trpn}/k_{tn_2}
	$trpnCo^{III}(aq)$	$tn_2Co^{III}(aq)$[b]	
1:1	⩽0.2	0.2	⩽1
2:1	8.2	2.3	3.6
4:1	42.0	7.3	5.8
8:1	>150.0	13.4	>10.0

[a]ADP = 0.020 *M*, 20.0 °C, pH 7.0. 1:1 complex pre-formed at pH 4.0 and 20 °C for 60 min at a concentration 0.3 *M* for both reactants. [b]Results from ref. 4.

Figure 1 summarizes results for the hydrolysis of 2,4-DNPP and $(2,4\text{-DNP})_2P$ in the presence of $trpnCo^{III}(aq)$. At the pH corresponding to maximum rates [which approximates the pH at which $trpnCo(OH)(OH_2)^{2+}$ is maximized in solutions of $trpnCo^{III}(aq)$] the diester reacts 25 times faster than in the presence of $tn_2Co^{III}(aq)$ at its pH maximum (otherwise comparable conditions); a similar comparison for the monoester favors trpn over tn_2 by a factor of 30 [8].

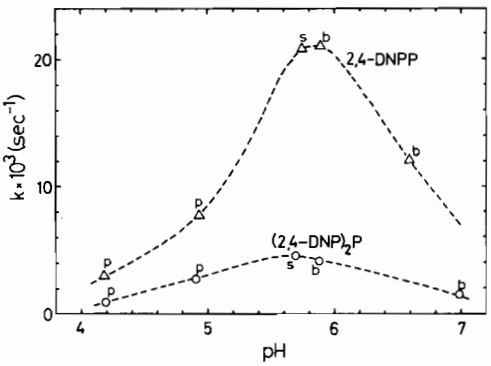

Fig. 1. trpnCo^{III}(aq) promoted hydrolysis of 2,4-DNPP and $(2,4\text{-DNP})_2P$. Ester, 5.0×10^{-5} *M*; Co^{III}, 1.25×10^{-3} *M*; buffer, 0.025 *M*; T = 25.0 °C; ionic strength = 0.50 *M*. Self-buffered, s; bis-tris, b; PIPPS, p.

It may be emphasized that in these experiments the rate is not close to saturation for the trpnCo^{III}(aq) concentrations used. The results therefore imply specific rate constants for the more active complexes which are much larger than the rate constants reported here.

The extraordinary effectiveness of trpnCo(OH)$(OH_2)^{2+}$ in promoting these phosphoryl transfer reactions relates to: (i) the *cis* requirement for the coordinated waters; (ii) the rapidity with which complexation takes place through water substitution; (iii) the involvement of complexes containing more than one cobalt center; (iv) the availability and reactivity of coordinated hydroxide on a suitably positioned cobalt.

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1 B. Anderson, R. M. Milburn, J. M. Harrowfield, G. B. Robertson and A. M. Sargeson, *J. Am. Chem. Soc., 99*, 2652 (1977).
2 P. W. A. Hübner and R. M. Milburn, *Inorg. Chem., 19*, 1267 (1980).
3 M. Hediger and R. M. Milburn, *J. Inorg. Biochem., 16*, 165 (1982).
4 M. Hediger and R. M. Milburn, in 'Phosphorus Chemistry', Am. Chem. Soc. Symposium Series No. 171, 1981, Ch. 43, pp. 211–216.
5 Methods used to prepare $(2,4\text{-DNP})_2P$ and 2,4-DNPP have been described [6]; the preparation of $[trpnCo(OH_2)_2](ClO_4)_3 \cdot 2H_2O$ will be described elsewhere.
6 G. Rawji and R. M. Milburn, *J. Org. Chem., 46*, 1205 (1981).
7 (a) H. R. Hulett, *Nature, 225*, 1248 (1970); (b) D. L. Miller and F. H. Westheimer, *J. Am. Chem. Soc., 88*, 1507 (1966).
8 G. Rawji and R. M. Milburn, to be published.

T11

Binding of Dioxouranium(VI) to Thiamine and Its Pyrophosphate Ester (Cocarboxylase) in Dimethylsulfoxide

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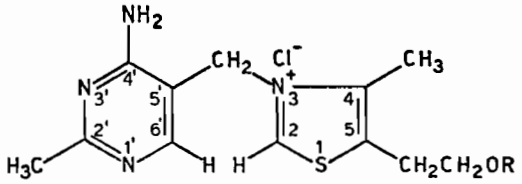
Thiamine hydrochloride (Vitamin B_1) is a necessary dietary constituent and its pyrophosphate ester (TPP) is the coenzyme cocarboxylase which catalyzes the decarboxylation of α-ketoacids in the presence of divalent metal ions (Mg(II), Mn(II), Co(II) *etc.*).



R=H Thiamine; $P_2O_7^{3-}$ Thiamine pyrophosphate (TPP)

A general mechanism of action of thiamine pyrophosphate has been proposed but there are still uncertainties on the role of metal ions and the nature of the bonding sites. In fact, Hadjiliadis *et al.* [1], on the basis of ^1H and ^{13}C NMR studies in DMSO-d_6 on the interaction of thiamine and its pyrophosphate ester with Pt(II) and Pd(II) concluded that the role of metal ions is to coordinate pyrimidine at N-1′ position in agreement with the results obtained by the X-ray structure of the Cd(thiamine)Cl_3 complex [2], whereas Gary and Adeyemo [3] through the same NMR and IR spectra showed that Zn(II), Cd(III) and Hg(II) are bound through the N-3′ position of the pyrimidine ring.

The binding of dioxouranium(VI) with thiamine and cocarboxylase, already studied by us in methanol solution [4–8], has been now analyzed by ^1H and ^{13}C NMR measurements in deuterated dimethylsulfoxide.

^1H NMR Spectra. Coordination of thiamine to dioxouranium(VI) caused a remarkable variation of the proton chemical shifts towards higher field, in particular of C-2′-CH_3 and C-6′-H protons. Such an upfield shift depends on the UO^{2+}/thiamine molar ratio and is very relevant for the protons adjacent to the N-1′ nitrogen of the ligand whereas no important effect is observed for the $-CH_2-CH_2-OH$ side-chain protons.

The spectrum of cocarboxylase upon UO_2^{2+} complexation exhibits a marked downfield shift of the protons proximal to the pyrophosphate group together with a slight change of the C-6′H chemical shift.