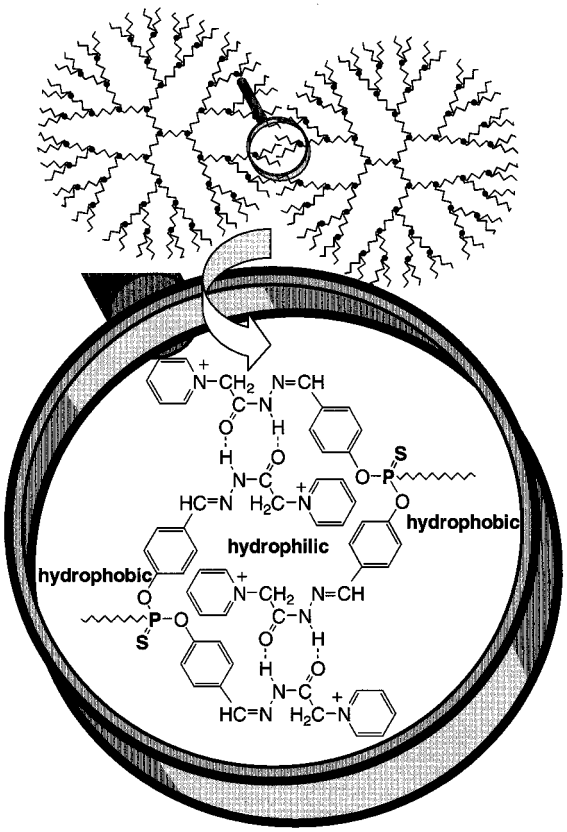

Figure 3. Supramolecular interactions (hydrogen bonds, $\pi-\pi$ aromatic stacking, hydrophobic effects) as driving forces for the formation of gels.

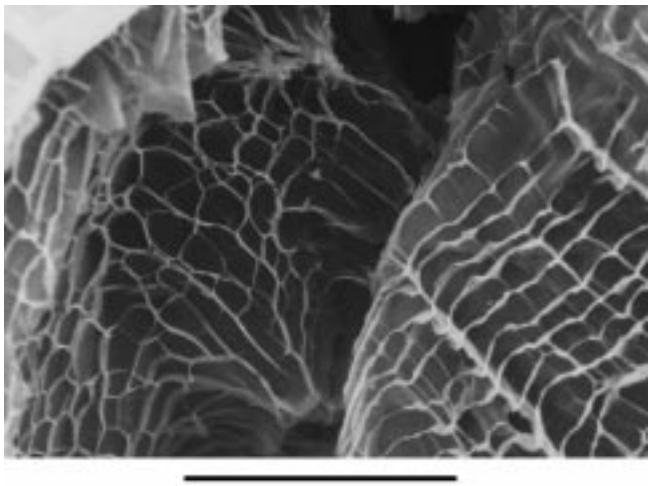

Figure 4. SEM image of a freeze-dried gel (**3-[G_4]**) (20 kV); bar: 200 μm.

In conclusion we have described a new type of gel based on phosphorus-containing dendrimers. These gels can be obtained under very mild conditions and allow the confinement of a number of active substances.

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trans-$[Fe(CN)_4(CO)_2]^{2-}$, a 21st Century [Fe(CN)(CO)] Compound**

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$[Fe^{II}(CN)_5(CO)]^{3-}$ was reported in the 19th century,[1] and $[Fe(CN)(CO)_4]^{1-}$ was characterized in the 20th century.[2] Here we report the synthesis and characterization of the third monomeric iron complex with exclusively CO and CN^- ligands.[3] The discovery of the [Fe(CN)(CO)] moieties at the catalytic centers of NiFe and Fe-only hydrogenases[4] dramatically increased interest in Fe compounds with CN^- and CO ligands.[5] These enzymes provided the first examples of either CO or CN^- as native ligands in a metalloprotein. Simple [Fe(CN)(CO)] complexes are possible intermediates in the biosynthesis of the $[Fe(CN)_y(CO)_x]$ centers in hydrogenases and are possible complexes in prebiotic chemistry.[6]

trans-$[Fe(CN)_4(CO)_2]^{2-}$ (**1**) is generated in solution by the simple addition of 4 equiv of NaCN to an aqueous solution of $FeCl_2 \cdot 4H_2O$ under an atmosphere of CO. The anion was isolated as the colorless crystalline solid $Na_2(dmf)_4$-**1**, which is

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stable in air for at least several months. As far as we can determine, this compound has never been described in the literature. This is surprising considering the simplicity of the synthesis and the nearly three centuries of interest in Fe – CN chemistry.[7]

The X-ray crystal structure of $Na_2(dmf)_4$-**1** (Figure 1) established the *trans* octahedral arrangement of the CO and CN ligands in the centrosymmetric $[Fe(CN)_4(CO)_2]^{2-}$ anion.[8] The Fe–CO distance (1.800(5) Å) and Fe–CN distances

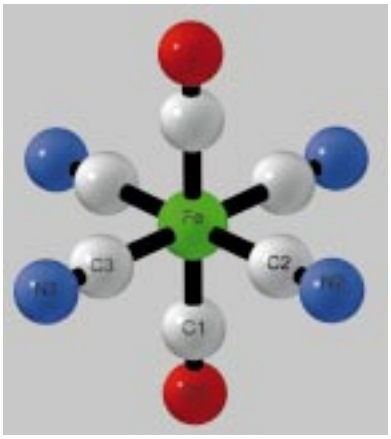

Figure 1. Structural diagram of $[Fe^{II}(CN)_4(CO)_2]^{2-}$. Selected bond lengths [Å] and angles [°]: Fe1-C1 1.800(5), Fe1-C3 1.923(3), Fe1-C2 1.929(4), C1-O1 1.122(5), C3-N3 1.150(4); C2-Fe1-C3 90.05(12), Fe1-C1-O1 178.8(4).

(1.926(4) Å) are consistent with those in other recently solved structures of [Fe(CN)(CO)] compounds.[5] *cis*-$[L_2Fe(CN)_4]$ complexes have been structurally characterized, where L_2 is a bidentate ligand such as ethylenediamine, bipyridine, or 1,10-phenanthroline,[9] but **1** is the first example of a *cis*- or *trans*-$[L_2Fe(CN)_4]$ complex in which L are monodentate ligands. Such $[L_2M(CN)_4]$ compounds in which L is monodentate are rare for the entire transition metal series. The Na cations and the DMF molecules combine with the $[Fe(CN)_4(CO)_2]^{2-}$ anions to create a two-dimensional array (Figure 2). The Na cations occur in pairs linked by two DMF molecules, and each Na cation is also coordinated by a terminal DMF molecule and to two NC groups of the anion. As a result, each cyano group bridges Fe and Na atoms.

The IR spectrum of $Na_2(dmf)_4$-**1** indicates that the *trans* stereochemistry is preserved in solution. As expected for a compound with D_{4h} symmetry, there are single CO and CN stretching bands at 1992 and 2104 cm^{-1} in DMF. There is no evidence for the *cis* isomer in a solution of the isolated product or in the original synthesis solution. These observations contrast with our investigations on a possible alternative synthetic route to **1**. The reaction of 4 equiv of NaCN with $[FeI_2(CO)_4]$ gives solutions that exhibit two equally intense CO stretching bands in Me_2SO at 2016 and 1960 cm^{-1}, consistent with a *cis* arrangement of CO ligands. Simple bonding considerations would suggest that the *cis* isomer of $[Fe(CN)_4(CO)_2]^{2-}$ would be more stable than the *trans* isomer.

The CO and CN stretching frequencies show a pronounced solvent dependence. In water, the CO band (2048 cm^{-1}) is shifted by 56 cm^{-1} to higher energy relative to that in DMF,

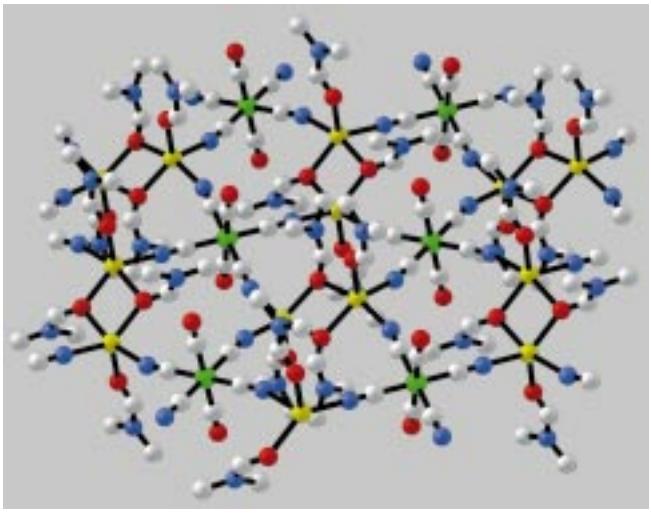

Figure 2. Structural diagram of the two-dimensional lattice showing the interaction of the Na cations with the $[Fe(CN)_4(CO)_2]^{2-}$ anions and DMF. Selected bond lengths [Å]: N3-Na1 2.410(3), N2-Na1 2.385(4), O3-Na1 2.339(3).

while the CN band (2104 cm^{-1}) remains virtually unchanged. The CO stretching band occurs at 2029 cm^{-1} in MeOH, and at 2005 cm^{-1} in CH_2Cl_2. Hydrogen bonding to the CN^- ligands decreases the σ-donor ability of these ligands with a resultant decrease in the electron density available for back-donation to the CO ligands.[10] The solid-state IR spectrum of $Na_2(dmf)_4$-**1**, which has CN and CO stretching bands at 2115 and 2025 cm^{-1}, suggests that the interaction of the Na cation with the $[Fe(CN)_4(CO)_2]^{2-}$ anion has an effect comparable to the hydrogen bonding in MeOH solution. The ^{13}C NMR spectrum of **1** in D_2O shows signals at $\delta = 206$ and 150, which are assigned to the CO and the CN^- ligands. Compound **1** undergoes quasireversible oxidation at +1.38 V (vs SCE) in DMF solution.

$[Fe(CN)_6]^{4-}$, $[Fe(CN)_5(CO)]^{3-}$, and **1** create a series of octahedral low-spin d^6 Fe^{II} complexes which enables comparisons of spectroscopic properties and redox potentials as CN^- is substituted by CO (Table 1). The trends are those expected for the substitution of a good σ-donor/weak π-acceptor CN^- ligand by a poor σ-donor/strong π-acceptor CO ligand. The $Fe^{3+/2+}$ couples shift by 1.155 and 1.125 V as CN^- ligands are stepwise replaced by CO ligands. This gives an experimental measurement of the stabilizing effect of CO versus CN^- for lower oxidation states. The oxidation states of the various redox states of iron-only hydrogenases remain unresolved.[11]

Table 1. Effect of CO/CN^- ligand substitution on spectroscopic and redox properties of $[Fe(CN)_{(6-x)}(CO)_x]^{n-}$ complexes.

	$\tilde{\nu}_{CN}$ [cm^{-1}] (H_2O)	$\delta_{^{13}C}$ of CN (D_2O)	Fe^{III}/Fe^{II} redox potential [V] (Me_2SO, vs SCE[a])
$K_4[Fe^{II}(CN)_6]$	2044[12]	177[13]	−0.90[10]
$Na_3[Fe^{II}(CN)_5(CO)]$	2075 (*cis*)[14]	162.5 (*cis*) 163.4 (*trans*)[15]	0.255[14]
$[Fe^{II}(CN)_4(CO)_2]^{2-}$	2104	150	1.38

[a] SCE = saturated calomel electrode.

  1433-7851/01/4014-2630 $ 17.50+.50/0

The reactivity of $[Fe^{II}(CN)_4(CO)_2]^{2-}$ and its use as a building block for solid-state materials are under active investigation.

Experimental Section

$Na_2(dmf)_4$-**1**: An aqueous solution (50 mL) of NaCN (0.417g, 8.51 mmol) was added dropwise to an aqueous solution (50 mL) of $FeCl_2 \cdot 4H_2O$ (0.422 g, 2.12 mmol) under a CO atmosphere. The reaction mixture was stirred under a CO atmosphere for 18 h. The water was removed under vacuum, and the residue was extracted with 30 mL of DMF. The product (0.520 g, 44% yield) was obtained by the addition of diethyl ether, filtration, and washing with cold ethanol.

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Synthesis, Biological, and Immunological Properties of Cyclic Peptides from *Plasmodium Falciparum* Merozoite Surface Protein-1**

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Malaria is the most important parasitic disease in humans, and in 1997 a malaria risk of varying degrees existed in 100 countries. In 92 of these, transmission included the malignant (*Plasmodium falciparum*) form of the disease, which causes 1.5 to 2.7 million deaths each year.

In spite of intensive efforts, not a single vaccine against a human parasitic disease is currently commercially available, and only one vaccine candidate, namely Spf66,[1] reached phase III clinical trials. Most efforts to develop synthetic peptide vaccines have focused on the use of short, linear B-cell epitopes to elicit the desired immune response. However, linear peptides are inherently flexible molecules and are proteolytically unstable in serum.[2] Conformationally restricted cyclic peptides have the potential to preserve the original secondary structure of the native proteins and in many cases this has been shown to constitute an important feature for a peptide to behave as a good immunogen.[3] Furthermore, it has long been known that the cyclization of a peptide may induce higher binding affinities and a greater degree of specificity in peptide–receptor interactions.[4]

The invasion process of malaria merozoites into human red blood cells (RBCs) is a crucial step in the life cycle of the parasite in the vertebrate host and gives rise to the blood stage part of the parasite cycle, which is responsible for the clinical manifestations of malaria.[5] The rationale of our approach was the identification of small, structurally defined peptide structures that mimic the interaction of the parasitic Merozoite Surface Protein 1 (MSP-1) from *P. falciparum* with the human RBC. Induction of antibodies to such mimics may be useful for studying and blocking these interactions.

To better characterize ligand–receptor interactions that are involved in the invasion process of RBCs, we studied the effect of the introduction of conformational constraints into a linear lead peptide. In parallel, we also studied the effect of peptide cyclization on epitope immunogenicity.

For this purpose, the central part of the 42-61 N-Terminal MSP-1 fragment (Peptide 1513: GYSLFQKEKMVL-NEGTSGTA) was cyclized by using a modified version of the backbone cyclization method.[6] The peptide 1513 plays a decisive role in the recognition of RBC receptors by malaria

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