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Lipophilic *N*-[2-Hydroxyimino-2-(pyridin-2-yl)ethyl]trialkylammonium Salts - - New Ligands for Metal Ion Extractions into Organic Solvents

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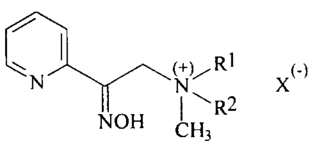
Abstract: Several lipophilic *N*-[2-hydroxyimino-2-(pyridin-2-yl)ethyl]trialkylammonium salts **1** were synthesized from the corresponding oxo compounds and hydroxylamine in the presence of Ni^{2+} ions which stabilize the oximes by chelation. Salts **1** are surfactants possessing a powerful chelating subunit. Their ability to extract different metal ions from aqueous solutions into organic solvents was tested by metal ion transport through a liquid membrane.

Keywords: complexes, liquid membrane, pyridines, oximes

Metal ion extraction from aqueous solutions into organic solvents has been of considerable interest for decades. A large number of studies dealing with this and related topics (e.g. with metal ion transport through liquid membranes) have been summarized and collected in many books and reviews.[1a] The effort to understand specific metal ion transport and partitioning reactions in living systems as well as possible applications (e.g. the development of new analytical methods,[1b] extraction processes in hydrometallurgy,[1c] waste water treatment,[1d,e] and treatment of radionuclides[1d-f] etc.) has stimulated extensive research in this area.



	R^1	R^2	X
1a	CH_3	C_8H_{17}	NO_3
1b	CH_3	$C_{10}H_{21}$	NO_3
1c	CH_3	$C_{12}H_{25}$	Br
1d	C_8H_{17}	C_8H_{17}	NO_3
1e	$C_{16}H_{33}$	$C_{16}H_{33}$	NO_3

Herein we wish to report an efficient method of synthesis of *N*-[2-hydroxyimino-2-(pyridin-2-yl)ethyl]-dialkylmethylammonium salts **1** and to comment upon possible utilization of these ligand-surfactants in metal ion extractions from aqueous solutions into organic solvents. A synthesis of salts **1a-c** possessing one hydrophobic alkyl chain and the testing of the hydrolytic activity of their chelates with transition metal ions was reported in our previous communication.[2] In the present study, we decided to investigate this type of compound as transition metal ion carriers through liquid membranes. Besides the above-mentioned salts **1a-c**, we synthesized and examined their double-chained analogues **1d,e**.

As described earlier,[2] salts **1a-c** can be synthesized in three steps starting from 2-acetylpyridine, the final step being the transformation of the corresponding *N*-[2-oxo-2-(pyridin-2-yl)ethyl]alkyldimethylammonium bromides **2a-c** using hydroxylamine hydrochloride in the presence of pyridine. Unfortunately, the

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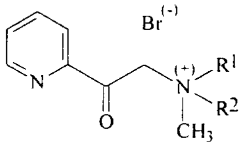
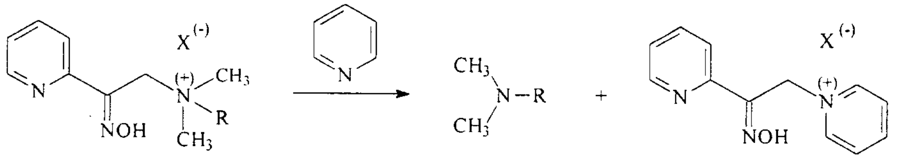


	R^1	R^2
2a	CH_3	C_8H_{17}
2b	CH_3	$C_{10}H_{21}$
2c	CH_3	$C_{12}H_{25}$
2d	C_8H_{17}	C_8H_{17}
2e	$C_{16}H_{33}$	$C_{16}H_{33}$

yields of these reactions were low (11 - 18%). Moreover, this method completely failed in the **attempted** syntheses of the double-chained salts **1d,e**. Careful analysis of the reaction mixtures resulting from the reactions of ketones **2** with hydroxylamine hydrochloride in pyridine revealed the presence of the corresponding trialkylamine hydrochlorides. A question arose as to which compound (ketone **2** or oxime **1**) decomposed and decreased the yield in the final step of the synthesis. Heating the ketone **2c** in the presence of an equimolar amount of pyridine in methanol-*d₄* in an NMR tube left the starting compound unchanged according to ^1H NMR. On the other hand, oxime **1c** afforded dodecyldimethylamine and *N*-[2-hydroxyimino-2-(pyridin-2-yl)ethyl]pyridinium bromide **3** under the same conditions (Scheme 1). This reaction was also performed on a preparative scale and the salt **3** isolated and its structure confirmed.[3a]



1 **3**

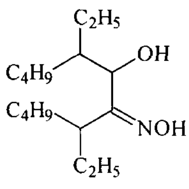
Scheme 1

To prevent the above-mentioned undesired reaction, we decided to employ the sterically hindered polymer bound base, poly(2,6-di-*tert*-butyl-4-vinylpyridine), instead of pyridine. Indeed, the yields increased up to approx. 40% in the case of salts **1a-c** possessing one hydrophobic alkyl chain. Nevertheless, synthesis of the double-chained salts **1d,e** did not succeed under these conditions.

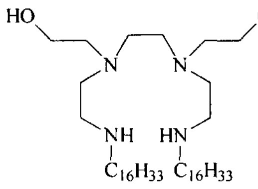
Finally, we tried to stabilize the oximes **1** by coordination. We assumed that donation of the unshared electron pairs of the pyridine and oxime nitrogens into the d-orbitals of a transition metal ion should prevent the nucleophilic substitution of the quaternary nitrogen whether this proceeded by an S_N1 or by an S_N2 mechanism.[4] We have found that Ni^{2+} ions in stoichiometric[5,6] amounts are especially suitable for this purpose. Their presence in the reaction mixture enabled preparation of the new ligand surfactants[3b,c] **1d** and **1e**, although in moderate yield (29 and 22%, respectively).[7] Using this procedure, the yields of the single-chained salts **1a-c** increased up to 60 – 70%. Salts **1** were liberated from their Ni^{2+} chelates using an excess of EDTA.

The ability of the ligand-surfactants **1** to extract different transition metal ions (Cu^{2+}, Ni^{2+} and Pd^{2+}) from aqueous solutions into organic solvents was tested by transport experiments through a liquid membrane. The transport cell[8] used was analogous to equipment described elsewhere.[1d,e] In all experiments, the concentration of salt **1** in the membrane was 1.0×10^{-3} M. The initial concentration of the metal ion in the buffered (pH 4.7) source phase was 5.0×10^{-3} M. Hydrochloric acid (0.1 M) served as the receiving phase. During the transport experiments, the concentration of the metal ion was monitored spectrophotometrically in all phases (Cu^{2+} and Ni^{2+} as *N,N*-diethyl dithiocarbamate complexes[9a] and Pd^{2+} as chelates with 2-pyridine aldoxime[9b]).

As evident from Fig. 1a, the rate of the Cu^{2+} transport increased with the lipophilicity of the single-chained salts **1a-c**. While **1a** did not transport Cu^{2+} at all, we observed both "uphill" transport (i.e. the final metal ion concentration in the receiving phase was higher than the one in the source phase) and the "shuttle" effect (more than a stoichiometric amount of the metal ion was transferred from the source phase into the receiving one) in the case of **1c**. Double-chained salts, especially dioctyl compound **1d**, are excellent Cu^{2+} carriers. Their efficiency is much higher than that of the industrial extractant **LIX-63** and is comparable with that of Menger's "magic" ligand[9a] **4** as verified by the transport experiments performed with these compounds (Fig. 1b). Surprisingly, Ni^{2+} is not transported by the double-chained salts **1d,e** at all. The only Ni^{2+} transfer observed was mediated by single-chained salts, the decyl compound **1b** being the most efficient of them (Fig. 1c). The octyl salt **1a** did not transport Ni^{2+} at all. As shown in Fig. 1d, double-chained salts **1d,e** can also transport Pd^{2+} nevertheless, the metal ion is accumulated in the membrane and 5 M hydrochloric acid is necessary to extract Pd^{2+} into the receiving phase.



LIX-63



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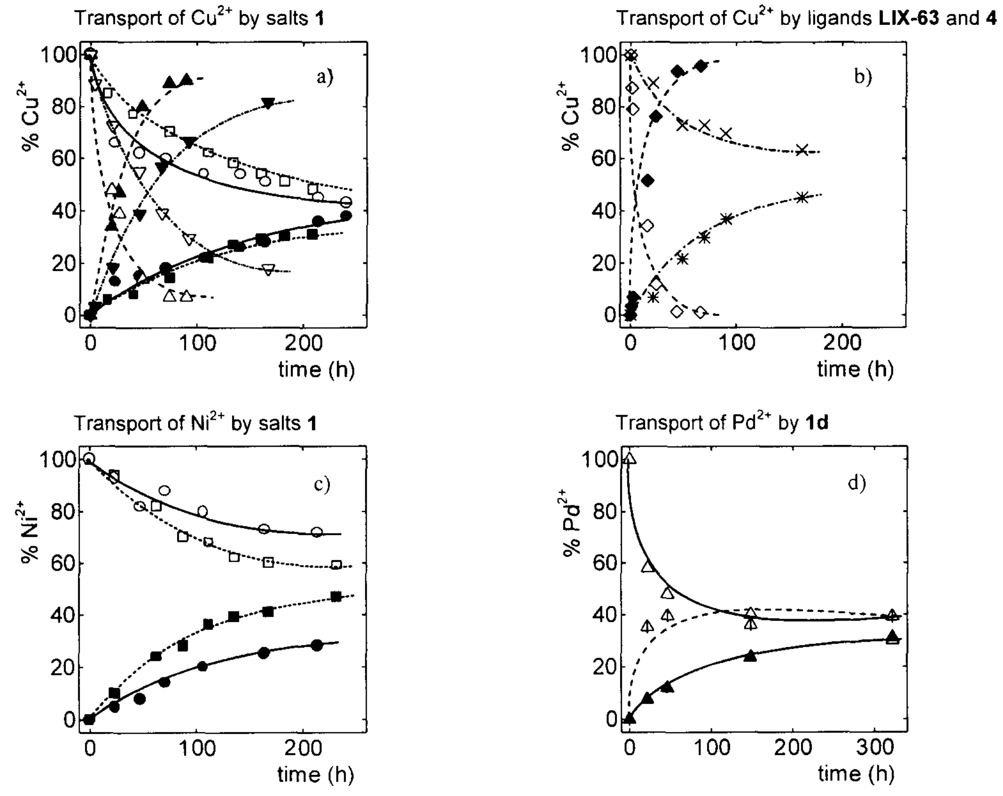

Fig. 1 Percentage of the initial metal ion in the source and receiving phase as a function of time. The conditions of the experiments are described in the text.
Carriers used in the experiments: **1b** (□), **1c** (O), **1d** (Δ), **1e** (∇), **4** (◇). Filled and empty symbols indicate data for the receiving and source phase, respectively. In the case of LIX63 (✱) and (×) indicate data for the receiving and source phases. Symbol (⟁) indicates data for the membrane in the Pd^{2+} transport.

These transport experiments clearly demonstrate that salts **1** represent versatile transition metal ion extractants, the efficiency and selectivity of which can be modified by the structure of the hydrophobic moiety of these ligand-surfactants.

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3. a) **3**: m.p. 191.5 – 193.5 °C; EA: calc. 49.00% C, 4.11% H, 14.29% N; found 49.77% C, 4.18% H, 14.51% N; ^{1}H NMR(DMSO-d_6): 6.00 s, 2H, CH$_2$; 7.49 ddd, 1H, J(5',4') = 7.3, J(5',6') = 5.0, J(5'3') = 1.6, (H-5'); 7.91 ddd, 1H, J(4',3') = J(4',5') = 7.6, J(4',6') = 1.6, (H-4'); 7.97 d, 1H, J(3',4') = 7.6, (H-3'); 8.13 dd, 2H, J(3,2) = J(3,4) = J(5,4) = = J(5,6) = 6.9, (H-3, H-5); 8.59 t, 1H, J(4,3) = J(4,5) = 8.2 (H-4); 8.64 d, 1H, J(6',5') = 4.9, (H-6'); 9.13 d, 2H, J(2,3) = J(6,5) = 6.8, (H-2, H-6); b) **1d** (isolated as pyridinium dinitrate): m.p. 81 – 83 °C; EA: calc. 55.90% C, 8.80% H, 13.58% N; found 55.10% C, 8.32% H, 13.56% N; ^{1}H NMR(DMSO-d_6): 0.87 t, 6H, J(8',7') 6.5 (H-8'), 1.20 bs, 20H, (H-3' – H-7'); 1.69 m, 4H, (H-2'); 2.93 s, 3H, (CH$_3$N$^+$); 3.22 t, 4H, J(1',2') = 8.2, (H-1'); 4.70 s, 2H, (N$^+$CH$_2$C=); 7.50 dd, 1H, J(5,4) = 7.3; J(5,3) = 5.2, (H-5); 7.95 m, 2H, (H-3, H-4); 8.63 d, 1H, J(6,5) = 4.4, (H-6); c) **1e**: m.p. 93 – 94 °C; EA: calc. 70.96% C, 11.31% H, 8.27% N; found 70.94% C, 10.80% H, 8.27% N; ^{1}H NMR(CDCl$_3$): 0.89 t, 6H, J(16',15') 6.6 (H-16'), 1.26 bs, 52H, (H-3' – H-15'); 1.80 m, 4H, (H-2'); 3.10 s, 3H, (CH$_3$N$^+$); 3.33 m, 4H, (H-1'); 4.80 s, 2H, (N$^+$CH$_2$C=); 7.28 m, 1H, (H-5); 7.70 ddd, 1H, J(4,3) = J(4,5) = 7.8, J(4,6) = = 1.7, (H-4); 8.11 d, 1H, J(3,4) = 8.1, (H-3); 8.50 d, 1H, J(6,5) = 4.6, (H-6).
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5. According to our previous results[6], we expected 1 : 2 metal : ligand stoichiometry.
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7. General procedure: 1.3 M aqueous solution of nickel nitrate was mixed with pyridine and ethanol (volumes 1 : 2 : 2). A blue Ni^{2+} complex of pyridine appeared immediately. Ketone **2** (2 moles/mole Ni^{2+}) and hydroxylamine hydrochloride (4 moles/mole Ni^{2+}) were added and the reaction mixture was stirred at 60 °C for 45 h. Pyridine was removed *in vacuo* and the residue was dissolved in 50% aqueous ethanol. Then a dihydrate of EDTA (6 moles/mole Ni^{2+}) was added to this solution and stirred at 60 °C for 3 h. The solid was filtered off and washed with 50% aqueous ethanol. The filtrate was extracted with chloroform, the extract dried with sodium sulfate and the solvent was evaporated. The crude product was dissolved in methanol and then treated with Amberlite IRA 400 (OH$^-$), neutralized with nitric acid, evaporated and crystallized from ethyl acetate (single-chained salts **1a-c**) or petroleum ether (double-chained salts **1d,e**).
8. A glass tube (48 mm and 44.5 mm were the external and the internal diameters, respectively) was immersed coaxially into a cylindrical glass vessel (internal diameter 57 mm) beneath the surface of the chloroform layer (70 ml), thus separating two aqueous phases: the source phase (50 ml) and the receiving phase (25 ml). The chloroform layer (liquid membrane) was stirred slowly by a mechanical stirrer keeping the phase interfaces motionless.
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