the data in [11], mp 97.0-97.7°C; the R_f 0.89 (a) coincided with the R_f value of compound XXI, obtained according to [1].

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SYNTHESIS OF MACROHETEROCYCLES — ANALOGS OF DIBENZO-CROWN COMPOUNDS.

4.* 15-18-MEMBERED PYRIDINE-CONTAINING CROWN COMPOUNDS

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By condensation of bridged, aromatic diamines, derivatives of o-aminophenol or o-aminothiophenol, with the diacyl chloride of 2,6-pyridinedicarboxylic acid under high dilution, 15-18-membered macrocyclic diamides containing a pyridine nucleus have been synthesized. The synthesized compounds were characterized by IR and PMR spectroscopy.

At the present time, a number of synthetic paths are known for obtaining macrocyclic polyamines and their metal complexes [2, 3]. Attempts to modify the structure of crown ethers so as to form macrocycles possessing the ability to selectively bind different metal cations led to the incorporation of various heterocyclic fragments in the macrocyclic ring. The most widespread methods of synthesizing such compounds are the condensation of heteroaromatic dialdehydes and diketones with primary diamines in the presence of a template ion [4] as well as the use of the technique of high dilution [3] with the formation of the corresponding macrocyclic Schiff base.

One of the most useful heterocyclic fragments that can be incorporated in a macrocyclic structure is the pyridine fragment. To obtain macrocyclic cryptands and diamines, primary diamines [5], diaza-crown ethers [6] and thioethers [7] are acylated with 6,6'-bis(chlorocarboxyl)-2,2'-dipyridyl. A porphyrin-like macrocycle was obtained by the high-temperature cyclization of 6,6'-dichloro-2,2'-dipyridyl in the presence of ammonium tetrachlorozincate [8]. The usual method of synthesizing aza-crown compounds is to condense sodium salts of sulfonyl derivatives of primary polyamines with 6,6'-bis(chloromethyl)-2,2'-dipyridyl [9].

*See [1] for Communication 3 in this series.

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TABLE 1. Characteristics of Compounds I-XII

Compound	Empirical formula	mp, °C	R_f ($CHCl_3$)	Yield, %	Compound	Empirical formula	mp, °C	R_f ($CHCl_3$)	Yield, %
I	$C_{21}H_{17}N_3O_4$	321...323	0,75	49	VII	$C_{30}H_{28}N_4O_6S$	255...258	0,82	50
II	$C_{22}H_{19}N_3O_4$	202...204	0,62	26	VIII	$C_{21}H_{17}N_3O_2S_2$	250...252	0,85	64
III	$C_{23}H_{21}N_3O_4$	209...210	0,78	17	IX	$C_{24}H_{23}N_3O_2S_2$	150...151	0,65	44
IV	$C_{24}H_{23}N_3O_4$	234...235	0,62	43	X	$C_{23}H_{21}N_3O_3S_2$	164...166	0,67	29
V	$C_{23}H_{21}N_3O_5$	244...246	0,35	52	XI	$C_{23}H_{21}N_3O_2S_3$	170...171	0,72	33
VI	$C_{23}H_{21}N_3O_4S$	201..202	0,49*	24	XII	$C_{30}H_{28}N_4O_4S_3$	241...243	0,70	17

*Benzene–ethanol, 100:1.

TABLE 2. PMR Spectral Data and IR for Macrocyclic Amides I-XII

Compound	Chemical shifts of protons δ, ppm (J, Hz)						IR spectra ν_{NH}, cm^{-1}
	CH_2—A (4H)	CH_2—X (4H)	X	Ar, m	NH, br.s (2H)	Py (J=8,0 Hz)	
I	4,38 d (J=9 Hz)	—	—	8,60 (2H); 6,96...7,15 (6H)	10,6	8,15t (1H); 8,55 d (2H)	3360
II	4,36 d.d (J=5, J=5 Hz)	—	2,39 m (2H)	8,60 (2H); 6,95...7,15 (6H)	10,41	8,12t (1H); 8,48 d (2H)	3350
III	4,24d (J=12 Hz.)	2,09 m	—	8,62 (2H); 6,95...7,15 (6H)	10,09	8,12 t (1H); 8,57 d (2H)	3370
IV	4,11 m	1,87 (6H)		8,60 (2H); 6,86...7,12 (6H)	9,52	8,10 m (1H)*; 8,32 m (2H)*	3250
V	4,26 m	3,91 m	—	8,53 (2H); 6,88...7,17 (6H)	9,74	8,12 t (1H); 8,25 d (2H)	3260
VI	4,37 d.d (J=5; J=5 Hz)	3,01 d.d (J=5; J=5 Hz)	—	8,43 (2H); 6,98...7,16 (6H)	10,00	8,11 t (1H); 8,51 d (2H)	3400
VII	4,37 m	2,71 m	2,40 s (3H); 7,50 m (4H)	8,51 (4H)**; 6,91...7,30 (6H)	10,00	8,12 m (1H)*	3240
VIII	3,20 m	—	—	8,51 (2H); 6,90...7,12 (6H)	11,68	8,18 m (1H)*; 8,36 m (2H)*	3280
IX	3,00 m	1,60 m (6H)		8,65 (2H); 7,07...7,48 (6H)	10,24	8,14 t (1H); 8,52 d (2H)	3360, 3480
X	3,03 d.d (J=5; J=6 Hz)	3,53 d.d (J=5; J=6 Hz)	—	8,51 (2H); 7,14...7,54 (6H)	10,57	8,11...8,22 m (3H)*	3340
XI	3,09 d.d (J=6; J=6,5 Hz)	2,69 d.d (J=7; J=6 Hz)	—	8,30 (2H); 7,19...7,54 (6H)	10,65	8,15 t (1H); 8,50 d (2H)	3340
XII	3,17...3,23 m (8H)		2,37 s (3H); 8,45 m (2H); 7,16...7,52 m (10H)		10,48	8,15 t (1H); 8,53 d (2H)	3330

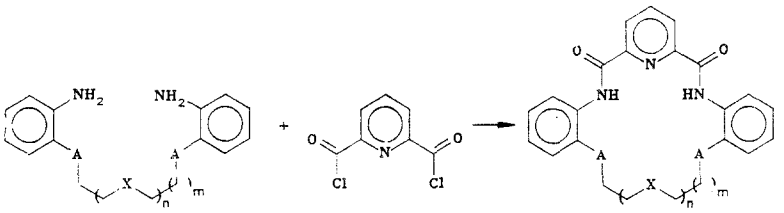
*SSCC [spin-spin coupling constant] lacking.

**Superposition of ortho-protons of the aromatic nuclei and β-protons of the pyridine fragment.

To synthesize cryptands containing a pyridine fragment, a method was proposed based on the use of the quaternization–dealkylation reaction [10]. A new method has been found for the synthesis of cyclohexapyridines [11, 12], which are examples of spherands, a promising class of complex forms with a rigid structure.

The available information on the use of pyridine-containing macroheterocycles of various structures gives grounds for assuming specific complex-forming properties [13-15].

For the purposes of analytical chemistry, we have synthesized a series of 15-18-membered macrocyclic systems incorporating different heteroatoms (O, N, S) and a pyridine nucleus (compounds I-XII). Unlike the macrocyclic diaza-crown compounds we described previously [1, 16, 17], compounds I-XII are macrocyclic amides:



I–XII

I–VII A=O, VIII–XII A=S; VI, XI X=S; VII, XII X=NTs; I–IV, VIII, IX n=0, V–VII, X–XII n=1; I, V–VIII, X–XII m=1, II m=2, III m=3, IV, IX m=4

Compounds I-XII were synthesized by acylating bridged aromatic diamines with the diacylchloride of pyridine-2,6-dicarboxylic acid under high dilution in benzene in the presence of pyridine. Reactant concentrations were 10^{-2} M. The synthesis of the starting diamines was described previously [1, 16-18]. The structure and purity of the resultant diamides, I-XII, was confirmed by TLC and elemental analysis (Table 1) as well as by the IR and PMR spectra (Table 2).

In the IR spectra of compounds I-XII, intense absorption bands are present in the 3340-3240 cm^{-1} region. These are due to the stretching vibrations of the free and bound amine groups in the secondary amides. The intense absorption bands of the stretching vibrations of the multiple bond of the carbonyl groups is found at 1690-1650 cm^{-1} ("Amide I"). In the 1600-1570 cm^{-1} region, there are absorption bands due to the deformation vibrations of the N–H and C–N bonds ("Amide II"). The "Amide III" band, of medium intensity, appears in the 1300-1270 cm^{-1} region. In the spectra of compounds VII and XII, which contain a tosyl group, bands are found for the antisymmetric (1340 cm^{-1}) and symmetric (1080 cm^{-1}) vibrations of the sulfonyl group. Intense, broad bands due to the stretching vibrations of the ether bond are found in the 1240-1140 cm^{-1} region of the IR spectra of amides I-XII. Vibrations of the C–S bond, usually appearing around 1325 cm^{-1}, are not characteristic.

Bands due to the stretching and deformation vibrations of the C–H bond in the pyridine fragment can be seen in the 3100-3000 cm^{-1} region (often superimposed on the ν_{C-H} band of the aliphatic CH_2 groups) and 1100-1030 cm^{-1}.

In the PMR spectra of amides I-XII, the weakest-field signal (11.68-9.52 ppm) belongs to protons of the amide group (see Table 2). The position of these signals differs from the position of analogous signals in the spectra of macrocyclic amides that do not contain a pyridine fragment (cf. [1, 17]). The observed shift of the signals by 2-3 ppm to weaker fields can be explained by the increased rigidity of the macrocycle when a pyridine fragment is introduced. This leads, obviously, to the convergence of the carbonyl groups and the amide protons and, correspondingly, to a weak-field shift of the signals of the amide protons. The fact that the weakest-field signal is that of the amide protons of the smallest of the macrocycles considered (15-membered VIII) can serve as confirmation. The carbonyl group also descreens the ortho-protons of the aromatic rings, leading to a 1.5-1.0 ppm shift of the ortho-proton signals to a weaker field relative to the remaining signals of aromatic ring protons. The signals of the protons of the pyridine fragment are shifted to a lower field relative to signals of the aromatic nuclei. The usually well-separated triplet from the proton in position 4 of the pyridine nucleus is located in the 8.10-8.18 ppm region, and the doublet from the protons in positions 3 and 5 is in the 8.25-8.57 ppm region. The signals from the protons of the methylene groups of the alkyl chain of the macrocycle are located in the regions typical of them (cf. [1, 16, 17]).

EXPERIMENTAL

The PMR spectra for solutions in $CDCl_3$ with a TMS internal standard were taken on Tesla BS-467 (60 MHz) and Bruker AC-250 (250 MHz) instruments. The IR spectra for solutions in chloroform in NaCl cuvettes were taken on a Specord IR-71 instrument. The thin layer and preparative chromatography was done on neutral Al_2O_3 II of standard activity according to Brockman and developed with iodine vapor.

The general procedure for preparing macrocyclic amides was described previously [17]. The solution of the diacyl chloride of pyridine-2,6-dicarboxylic acid is prepared in benzene and the solutions of the starting diamines, in dioxan or pyridine. The characteristics of compounds I-XII are presented in Tables 1 and 2. The elementary analyses correspond to the calculated values.

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