Potentiometric Studies of the Lithium Interaction with Urea and N-Methylacetamide in Aqueous Solution

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Potentiometric measurements of the K^+ and Li^+ activity in the presence of 4M urea or N-methylacetamide have been performed. The results support the view that Li^+ associates with amides.

The tendency of lithium ions to interact with amides is known to be considerable[1, 2]. Li^+ interactions with polypeptides[3–5] and a protein[6] have also been reported. Both spectroscopic data and theoretical calculations indicate that Li^+ binds to the amide carbonyl oxygen[7]. Such studies possibly offer a means of understanding the mode of action of Li salts as denaturants for biopolymers.

It appeared likely that further evidence for an association of Li^+ with amides can be found from potentiometric data. Therefore measurements of the Li^+ activity in strong aqueous solutions of urea and N-methylacetamide (NMA) using an ion selective electrode were carried out. For comparison purposes the behaviour of K^+ was examined, too.

Experimental

Since a laboratory-made homogeneous matrix membrane electrode (details about this kind of electrodes are described elsewhere[8]) made from 4% (w/w) valinomycin, 50% diphenyl ether, and 46% poly(vinyl isobutyl ether) exhibited a very sluggish response in the presence of urea and NMA, a K^+ sensitive glass electrode and a Na^+ sensitive glass electrode (for the Li^+ determinations) were used. These electrodes required a few minutes for the attainment of steady potentials. Electrode blanks of the electrodes 9602/8 and 9601/8, that is stems and bulbs, were provided by Jenaer Glaswerk Schott u. Gen., Mainz. The internal fillings were 10^{-2} M in KCl and 10^{-4} M in KOH or 10^{-2} M in LiCl and 10^{-4} M in LiOH, respectively. As inner reference electrodes silver-silver chloride electrodes were used. In contrast to the Li^+ electrode the K^+ electrode exhibited a p_H dependent slope factor at higher p_H values (p_H 11, 52.5 mV/decade). E.m.f. measurements were carried out at 25 °C in a U-shaped glass tube. The reference electrode of the restrained-flow type, which allowed a discontinuous renewal of the liquid junction, has been previously described[9]. The reproducibility was ± 2 mV.

Urea (analytical grade; Merck) and NMA (purum, 0.05% acetic acid; Merck) were used without further purification. The solutions containing the amides were freshly prepared. With regard to the H^+ response of glass electrodes the p_H of all solutions was raised by addition of KOH or LiOH. The NMA solutions were made 10^{-3} M in KOH or LiOH in order to neutralize the acetic acid and to reach a p_H region where the titration curves are flat. Table 1 shows the p_H values of the examined solutions as a function of their composition.

Table 1. p_H values of alkaline KCl and LiCl solutions in the absence and in the presence of 4 M urea or 4 M NMA.

c_{K^+,Li^+} mol l^{-1}	c_{OH^-} mol l^{-1}	no amide	urea	NMA
10^{-2}	10^{-3}	11.0	11.3	11.1
10^{-3}	10^{-3}	11.0	11.3	11.1
10^{-2}	10^{-4}	9.3	9.8	
10^{-3}	10^{-4}	9.3	9.8	

Results and Discussion

The results of the activity measurements are summarized in Table 2. Within the experimental error the activity of K^+ is not affected by 4 M urea at p_H 9.8 and 11.3. With Li^+ a decrease of the activity appears which seems to exceed the experimental uncertainty. Additional measurements in 8 M urea solutions at p_H 10.1 yielded shifts of + 3.0 and

Table 2. Potential shifts (in mV) and activity ratios (in parantheses) of K^+ and Li^+ in the presence of 4 M urea or 4 M NMA. Positive shifts are related to an increase in activity compared with the corresponding amide free solutions and vice versa. The activity ratio is given by a'/a'', where $'$ and $''$ denote the activity in the presence and in the absence of amide (ion activities were calculated by the Kielland method[10]).

c_{K^+,Li^+} mol l^{-1}	c_{OH^-} mol l^{-1}	urea K^+	urea Li^+	NMA K^+	NMA Li^+
10^{-2}	10^{-3}	−2.3	−4.6 (0.83)	+21.9 [a] (2.1)	+12.8 (1.7)
10^{-3}	10^{-3}	−1.6	−4.0 (0.85)	+25.1 [a] (2.6)	+25.7 (2.8)
10^{-2}	10^{-4}	−0.9			
10^{-3}	10^{-4}	−0.1			

[a] These values were corrected with regard to the sub-Nernstian behaviour of the K^+ electrode in alkaline solutions.

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– 8.8 mV for K^+ and Li^+, respectively. On assuming that with K^+ the shift merely reflects an effect of the medium, we may conclude that Li^+ associates with urea.

In the presence of NMA a considerable increase of the activities of K^+ and Li^+ is observed. This finding falls in line with activity measurements on salts in pure NMA reported by Wood et al.[11] and may be due to the extraordinarily high dielectric constant of the amide. With the solutions containing K^+ nearly the same e.m.f. shifts are obtained. This behaviour implies absence of an electrode malfunction caused by interfering ions.

The e.m.f. shifts in the case of Li^+ strongly depend on the Li^+ concentration. With the solution containing 10^{-2} M Li^+ the shift is essentially lower than with 10^{-2} M K^+. As the Na^+ electrode is $10^2 – 10^3$ times more sensitive to Na^+ than to Li^+[12], a Na^+ interference is possible. Taking into account that the presence of Na^+ can only raise the e.m.f. shift, we need not exclude an association of Li^+ with NMA at the 10^{-2} M level. Therefore our result is consistent with those of the authors mentioned above. Finally, it may be noted that a concentration dependent shift can be caused by a cooperative interaction between Li^+ and NMA in which the competition for available ligands forces the electrolyte to associate with the amide. This explanation has been applied to amide solutions containing more than 5 M LiCl[13].

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