New examples of ring–chain tautomeric conversions

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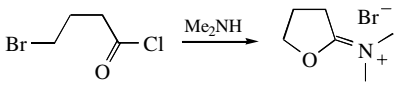
A new type of ring–chain tautomerism, which consists in the reversible conversion of γ-halobutyric acid dialkylamides into dialkyl(tetrahydro-2,2-furylidene)ammonium halides, was found.

Previously,[1] an attempt to synthesise γ-bromobutyramide by the interaction of a corresponding acid chloride with an excess of dimethylamine resulted in the crystalline product $C_6H_{12}BrNO$. Based on potentiometric titration data and the IR spectrum (C=N$^+$, 1699 cm^{-1}), this product was identified as dimethyl(tetrahydro-2,2-furylidene)ammonium bromide **1**.



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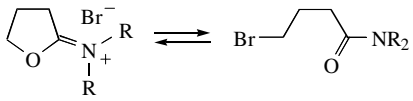
In a study of cyclic salt **1** by ^{1}H NMR spectroscopy,† we found that it occurs in solution in an equilibrium with γ-bromobutyric acid dimethylamide **2**. Analogous transformations were also observed in solutions of diisopropyl derivative **3**, which was not described previously. Here we consider this tautomeric conversion.



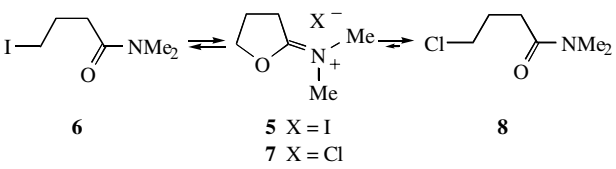
1 R = Me
3 R = Pr^i

2 R = Me
4 R = Pr^i

As would be expected, the temperature and the nature of the solvent affect the state of this equilibrium (Table 1). Thus, the ratio between cyclic and linear tautomers **1** and **2**, respectively, was ~42/58 in a nonpolar solvent ($CDCl_3$) at 303 K. As the temperature was increased to 318 or 333 K, this ratio became equal to 20/80 or 10/90, respectively (see Figure 1). At the latter temperature, the non-equivalence of the protons of methyl groups in amide **2** disappeared (this non-equivalence was due to a barrier of rotation about the C–N bond characteristic of alkylamides). As the solution was cooled to the initial temperature, the equilibrium system returned to its initial state.

Equilibrium **1**–**2** (**3**–**4**) in [$^2H_6$]DMSO and D_2O solutions was almost completely shifted towards cyclic salts **1**, **3**.

The replacement of the bromine atom in the parent molecule of **1** with iodine did not dramatically change the behaviour of the test system: the ratio between tautomers **5/6** was ~67/33 in a solution in $CDCl_3$ at 303 K. At the same time, the ^{1}H NMR spectrum of chloride **8**,[2] which is a mobile liquid, measured under the same conditions exhibited only traces (~0.1%) of cyclic species **7**. In this case, its diagnostic signal at δ 5.02 ppm (H_2C-5) practically disappeared on heating the solution to 333 K.



6

5 X = I
7 X = Cl

8

Table 1 Ratios between tautomers **1/2**, **3/4** and **5/6** in 0.1 M solutions in $CDCl_3$ at different temperatures (^{1}H NMR data).

T/K	**1/2** (%)	**3/4** (%)	**5/6** (%)
293	—	—	73/27
303	42/58	92/8	67/33
318	20/80	84/16	43/57
333	10/90	70/30	25/75

† *Dimethyl(tetrahydro-2,2-furylidene)ammonium bromide* **1** as very deliquescent colourless crystals was prepared in accordance with a previously described procedure.[1]

^{1}H NMR spectrum of a mixture of salt **1** and *4-bromobutanoic acid dimethylamide* **2** (200.13 MHz, $CDCl_3$, 303 K) δ: 2.60 (m, 2H, 4-H), 3.36 (s, 3H, Me), 3.52 (s, 3H, Me), 3.64 (t, 2H, 3-H, *J* 7.8 Hz), 5.01 (t, 2H, 5-H, *J* 7.5 Hz) (**1**); 2.19 (m, 2H, 3-H), 2.49 (t, 2H, 2-H, *J* 6.8 Hz), 2.94 (s, 3H, Me), 3.02 (s, 3H, Me), 3.51 (t, 2H, 4-H, *J* 6.2 Hz) (**2**).

Diisopropyl(tetrahydro-2,2-furylidene)ammonium bromide **3** was synthesised analogously as colourless crystals (from a $CHCl_3$–Bu^{t}OMe mixture) with mp 173–174 °C. IR (KBr, ν/cm^{-1}): 668, 776, 824, 916, 956, 1052, 1140, 1204, 1280, 1328, 1380, 1436, 1464, 1668 (C=N), 2980. Found (%): C, 47.76; H, 7.95; Br, 32.00; N, 5.60. Calc. for $C_{10}H_{20}BrNO$ (%): C, 48.01; H, 8.06; Br, 31.94; N, 5.60.

^{1}H NMR spectrum of a mixture of salt **3** and *4-bromobutanoic acid diisopropylamide* **4** (200.13 MHz, $CDCl_3$, 303 K) δ: 1.46 (d, 6H, 2Me, *J* 6.6 Hz), 1.47 (d, 6H, 2Me, *J* 6.9 Hz), 2.56 (m, 2H, 4-H), 3.83 (t, 2H, 3-H, *J* 8.1 Hz), 3.91 (sept, 1H, *H*CMe$_2$, *J* 6.9 Hz), 4.32 (sept, 1H, *H*CMe$_2$, *J* 6.6 Hz), 5.05 (t, 2H, 5-H, *J* 7.4 Hz) (**3**); 1.18 (d, 6H, 2Me, *J* 7.0 Hz), 1.33 (d, 6H, 2Me, *J* 6.4 Hz), 2.15 (m, 2H, 3-H), 2.44 (t, 2H, 2-H, *J* 7.2 Hz), 3.49 (t, 2H, 4-H, *J* 6.2 Hz), the signals of *H*CMe$_2$ protons overlapped with other signals (**4**).

Dimethyl(tetrahydro-2,2-furylidene)ammonium iodide **5** (unstable) was prepared from salt **1** by the treatment with an excess of NaI in a MeCN solution at room temperature. Mp 147–149 °C (from a MeCN–Bu^{t}OMe mixture). IR (KBr, ν/cm^{-1}): 668, 776, 824, 916, 956, 1052, 1140, 1204, 1280, 1328, 1380, 1436, 1464, 1668 (C=N), 2980.

^{1}H NMR spectrum of a mixture of salt **5** and *4-iodobutanoic acid dimethylamide* **6** (200.13 MHz, $CDCl_3$, 303 K) δ: 2.63 (m, 2H, 4-H), 3.36 (s, 3H, Me), 3.50 (s, 3H, Me), 3.61 (br. t, 2H, 3-H, *J* 8.1 Hz), 5.02 (t, 2H, 5-H, *J* 7.4 Hz) (**5**); 2.14 (m, 2H, 3-H), 2.44 (t, 2H, 2-H, *J* 6.9 Hz), 2.94 (s, 3H, Me), 3.02 (s, 3H, Me), 3.30 (t, 2H, 4-H, *J* 6.5 Hz) (**6**).

Dimethyl(tetrahydro-2,2-furylidene)ammonium chloride **7**: ^{1}H NMR (300.13 MHz, D_2O, 333 K) δ: 2.40 (m, 2H, 4-H), 3.17 (t, 2H, 3-H, *J* 8.3 Hz), 3.24 (s, 3H, Me), 3.29 (s, 3H, Me), 4.85 (t, 2H, 5-H, *J* 7.4 Hz).

4-Chlorobutanoic acid dimethylamide **8**:[2] ^{1}H NMR (300.13 MHz, $CDCl_3$, 298 K) δ: 2.12 (m, 2H, 3-H), 2.49 (t, 2H, 2-H, *J* 6.9 Hz), 2.95 (s, 3H, Me), 3.02 (s, 3H, Me), 3.64 (t, 2H, 4-H, *J* 6.2 Hz).

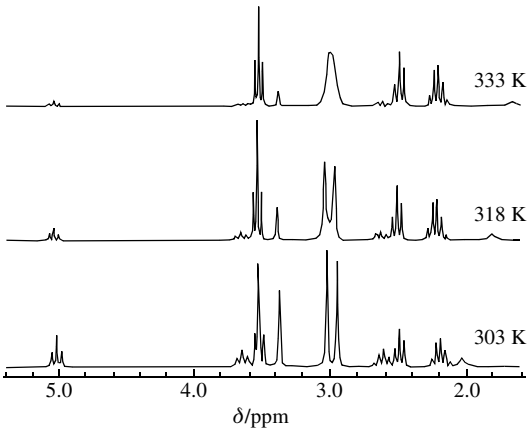


Figure 1 ^{1}H NMR spectra (200.13 MHz, $CDCl_3$) of a 0.1 M solution of a mixture of salt **1** and amide **2** at different temperatures.

However, in a [$^2H_6$]DMSO solution, the ratio between cyclic and linear species **7** and **8**, respectively, was ~14/86 at 303 K or ~11/89 at 333 K, whereas only cyclic tautomer **7** was detected in a solution in D_2O. In this case, its hydrolysis with the formation of butyrolactone occurred at a noticeable rate.

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References

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