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Reactions between Azolium Salts and Nucleophilic Reagents

II. Bromo-1,2,3-triazolium Salts and Sodium Hydroxide

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1-Methyl-3-benzyl-monobromo-1,2,3-triazolium salts (Ib) or (IVb), when dissolved in base, give an equilibrium mixture of (Ib), (IVb), the dibromo salt (IIb), and the unsubstituted salt (IIIb). The equilibrium mixture then reacts *via* the route E. The same route was followed when unsubstituted triazolium salts (IIIb) or (IIIc) were treated with *N*-bromoacetamide and aqueous base. Under the same conditions, (IIId) afforded a mixture of the triazolio-oxides (V), (VI), (VII), and (VIII). The effect of substituents on the rate of the base-catalyzed deuterium exchange of the heteroarometic protons of triazolium salts is largely inductive. The exchange rates furnish information about the relative reactivity of halonium ion acceptors and donors.

The reaction between 1,3-dimethyl-4-bromo-1,2,3-triazolium *p*-toluenesulfonate (Ia) and aqueous sodium hydroxide was previously described.[1] The first step in this reaction is a rapid establishment of the equilibrium A_1, leading to the formation of (IIa) and (IIIa), most likely *via* the anion (IXa). Subsequently, the bromo-compounds (Ia) and (IIa) undergo nucleophilic substitution to (Va) and (VIa). The corresponding reactions have now been studied with a number of other 1,2,3-triazolium salts.

These were prepared by heating alkyl tosylates with 1-substituted 4-bromo-1,2,3-triazoles, resulting in quaternization of the 3-position.[2–4]

When 1-benzyl-3-methyl-4-bromo-1,2,3-triazolium tosylate (Ib) was dissolved in 1 N aqueous potassium hydroxide at room temperature, NMR-spectra revealed the immediate, partial conversion into 1-methyl-3-benzyl-4,5-dibromo-1,2,3-triazolium tosylate (IIb), 1-methyl-3-benzyl-4,5-dibromo-1,2,3-triazolium tosylate (IIIb), and 1-methyl-3-benzyl-4-bromo-1,2,3-triazolium tosylate (IVb). Since the monobromo salt (IVb), or a mixture of the unsubstituted salt (IIIb) and the dibromo salt (IIb), yielded the same mixture of all four salts when dissolved in aqueous potassium hydroxide, equilibria A_1 and A_2 obviously exist in aqueous base. Since the heteroaromatic protons of (Ib), (IIIb), or (IVb) are rapidly exchanged with deuterium in the presence of base and deuterium oxide (Table 2), the equilibria A_1 and A_2 are undoubtedly

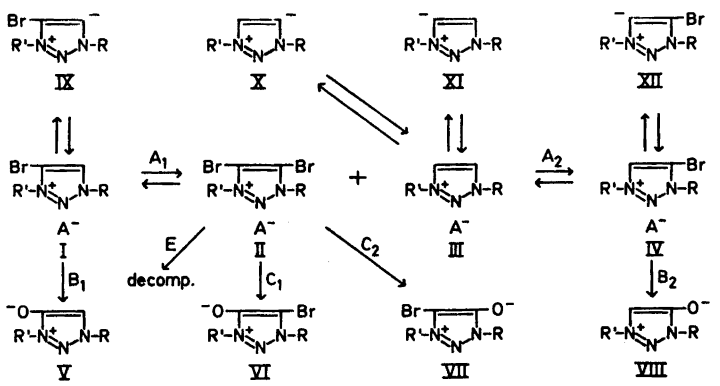
established *via* the anions (IXb), (Xb), (XIb), or (XIIb), in analogy with previous results.

If the equilibrium mixture of the four salts (Ib), (IIb), (IIIb), and (IVb) was kept at room temperature in aqueous base, further reactions took place. After the reaction was complete, monitored from the NMR-spectra, (IIIb) could be isolated in 41 % yield; in addition, an unidentified oil was produced. The same products were produced much more rapidly when the reaction was carried out at 100°. Nucleophilic substitution of the bromine of compounds (Ib), (IIb), or (IVb) would be expected to yield one or more of the triazolio-oxides (Vb), (VIb), (VIIb), or (VIIIb), none of which were observed. Separate experiments showed that these four compounds were stable towards aqueous base under the conditions used, and it must therefore be concluded that these triazolio-oxides were not formed at all. That the oily product resulted from base-catalyzed decomposition of the dibromo-compound (IIb), at least to the extent of 41 % (corresponding to the yield of (IIIb)), appeared from the fact that treatment of pure (IIb) with aqueous base gave the same oily product apparently not containing any 1,2,3-triazole-derivatives.

It was previously found[1] that treatment of the 1,3-dimethyl-triazolium salt (IIIa) with *N*-bromoacetamide resulted in formation of the dibromo-compound (IIa), which in the presence of base was immediately converted into the triazolio-oxide (VIa). Treatment of (IIIb) with *N*-bromoacetamide in aqueous base afforded as the sole product the oil described above. Hence, (IIIb) is probably converted into (IIb), which subsequently decomposes.

The use of *N*-bromoacetamide is of value in cases where the bromo-triazolium salts are not readily available. Thus, 1-methyl-3-phenyl-1,2,3-

Scheme 1



	R	R'
a	CH_3	CH_3
b	$CH_2C_6H_5$	CH_3
c	$CH_2C_6H_5$	$CH_2C_6H_5$
d	C_6H_5	CH_3

A = p-$CH_3C_6H_4SO_3$, when not otherwise stated.

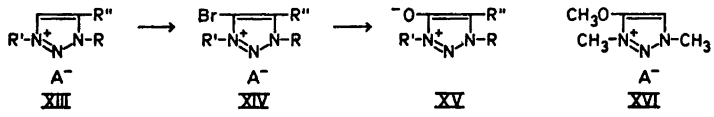
triazolium tosylate (IIId) and *N*-bromoacetamide (molar ratio 1/1) in aqueous base, afforded, besides unchanged starting material, 1-methyl-3-phenyl-5-bromo-1,2,3-triazolio-4-oxide (VId) and 1-phenyl-3-methyl-5-bromo-1,2,3-triazolio-4-oxide (VIId) (ratio 3.1/1) as the major products. In addition, minor amounts of 1-methyl-3-phenyl-1,2,3-triazolio-4-oxide (VIIId) and 1-phenyl-3-methyl-1,2,3-triazolio-4-oxide (Vd) (ratio 1/3.3) were produced. The four compounds were identified by IR- and NMR-spectroscopy (*cf.* Experimental and Table 3). Moreover, (VIId) could be debrominated to the previously described (VIIId).[14] Likewise (VId) could be converted into (Vd). NMR-spectra, recorded during the reaction, indicated that (IIId) is rapidly brominated, and an equilibrium mixture of (Id), (IId), (IIId), and (IVd) results, (Id), (IId), and (IVd) then give the four triazolio-oxides by displacement and proton-abstraction.*

NMR-spectra showed that the rate of triazolio-oxide formation was slower than that of bromination. Therefore, the substitution is the rate-limiting step. In analogy with previous results,[1] it may be assumed that the reaction is kinetically controlled. Hence, the product-distribution is determined by ratio between the velocity constants of the steps B_1, B_2, C_1, and C_2. The B_1/B_2 ratio was 3.3/1, the C_1/C_2 ratio was 1/3.1, and the $(B_1+B_2)/(C_1+C_2)$ ratio was 1/11.7. With a 1/2.5 molar ratio between (IIId) and *N*-bromoacetamide, the bromo-triazolio-oxides (VId) and (VIId) became the sole products. The C_1/C_2 ratio was 1/2.3.

Treatment of 1,3-dibenzyl-1,2,3-triazolium tosylate (IIIc) with *N*-bromoacetamide in aqueous base gave only oily material, probably arising by decomposition of the 4,5-dibromo-derivative (IIc), in analogy with the results obtained from (IIIb). No triazolio-oxides could be detected.

1,5-Dimethyl-3-phenyl-1,2,3-triazolium tosylate (XIIIa) reacted very slowly with *N*-bromoacetamide and sodium hydroxide at room temperature as expected from the exchange rate (see below). Again, displacement of bromine with hydroxylic ion is relatively slow as in other monobromo-1,2,3-triazolium salts (see below). At elevated temperature, however, 1,5-dimethyl-3-phenyl-1,2,3-triazolio-4-oxide (XVa) was formed in 24 % yield. Similarly, 1,4-di-

Scheme 2



	R	R'	R''
a	CH_3	C_6H_5	CH_3
b	C_6H_5	CH_3	CH_3

A = p-$CH_3C_6H_4SO_3$

* The possibility that the triazolio-oxides (VIIId) and (Vd) are the species undergoing bromination to (VId), and (VIId), was excluded when a separate experiment showed that (VIIId) did not react with *N*-bromoacetamide under the conditions of the reaction.

methyl-3-phenyl-1,2,3-triazolium tosylate (XIIIb) afforded 1,4-dimethyl-3-phenyl-1,2,3-triazolio-4-oxide (XVb).

The deuterium exchange rates of the heteroaromatic ring protons of a series of 1,2,3-triazolium tosylates are shown in Table 2. The signals of the 4- and 5-protons of (IIId) were assigned by comparison with the heteroaromatic proton signals in 1,5-dimethyl-3-phenyl-1,2,3-triazolium tosylate (XIIIa) and 1,4-dimethyl-3-phenyl-1,2,3-triazolium tosylate (XIIIb). From this pair it appears that a proton adjacent to an *N*-methyl group is more shielded than one adjacent to an *N*-phenyl group (Table 1). The exchange rates indicate, *inter alia*, that heteroaromatic protons in 2- and 3-position to an *N*-phenyl group are, respectively, about 31 and 13 times more acidic than those in the corresponding *N*-methyl-substituted salt (IIIa). The exchange rates of the monobromo compounds (Ib) and (IVb) indicate that a heteroaromatic proton in 2-position to an N-benzyl group is 1.2 times more acidic that a proton in the

Table 1. NMR-spectroscopic data of 1,2,3-triazolium tosylates.[a]

Compound	NMR					
	H_4 ppm	H_5 ppm	$J_{H_4H_5}$ Hz	NCH_3 ppm	NCH_2 ppm	CCH_3 ppm
1,3-Dimethyl-triazolium tosylate (IIIa) [b]	8.50	8.50		4.32 4.32		
1-Methyl-3-benzyl-triazolium tosylate (IIIb)	8.55	8.55		4.34	5.83	
1-Methyl-3-phenyl-triazolium tosylate (IIId)	9.05	8.75	1.7	4.50		
1,3-Dibenzyl-triazolium tosylate (IIIc)	8.62	8.62			5.87 5.87	
1,4-Dimethyl-3-phenyl-triazolium tosylate (XIIIb)		9.09		4.43		2.44
1,5-Dimethyl-3-phenyl-triazolium tosylate (XIIIa)	9.52			4.27		2.60
1,3-Dimethyl-4-methoxy-triazolium tosylate (XVI)		8.08		4.20 3.97		4.14 [c]
1,3-Dimethyl-4-bromo-triazolium tosylate (Ia) [b]		8.67		4.35 4.26		
1-Methyl-3-benzyl-4-bromo-triazolium tosylate (IVb)	8.77			4.40	5.90	
1-Benzyl-3-methyl-4-bromo-triazolium tosylate (Ib)		8.79		4.32	5.89	

[a] NMR-spectra were obtained in deuterium oxide with DSS as an internal standard. [b] The compound was prepared as described previously.[1] [c] OCH_3-signal; identification, see Ref. 13.

3-position. The relative average exchange rate of the heteroaromatic protons in (IIIb), which contains no bromine, is 2.2. Consequently, an *N*-benzyl group activates the protons in 2- and 3-position 2.4 and 2.0 times, respectively. Introduction of a bromine atom increases the acidity of the adjacent proton with a factor of about 450, whereas introduction of a *C*-methyl group decreases the acidity of the adjacent proton *ca.* 13 times. A methoxy group increases the acidity by a factor of 1.8. The effect of two (or more) groups seems to be roughly additive. The combined results indicate that bromine atoms, methoxy-, *N*-phenyl, and *N*-benzyl-groups stabilize the transition state corresponding to the "ylide"-anion of the triazolium salts. The stabilization is of the same order of magnitude in both the 2- and the 3-position. Consequently, the stabilizing effect is largely inductive, what appears reasonable, since the lone pair orbital

Table 2. Deuterium exchange rates of 1,3-disubstituted-1,2,3-triazolium salts.

Compound	Proton	pD	$T_{½}$ [a] min	Relative rate
1,3-Dimethyl-triazolium tosylate (IIIa)	H_4	9.86 [b]	13.2	1.00
1-Methyl-3-benzyl-triazolium tosylate (IIIb)	H_4 H_5	9.86 [b]	6 [e] 6 [e]	2.2 2.2
1-Methyl-3-phenyl-triazolium tosylate (IIId)	H_4 H_5	7.96 [c]	33.5 79.0	31 13
1,3-Dibenzyl-triazolium bromide [d] (IIIc)	H_4	9.86 [b]	2.3	5.7
1-Benzyl-3-phenyl-triazolium tosylate	H_4 H_5	7.96 [c]	26.2 39.7	40 25
1,4-Dimethyl-3-phenyl-triazolium tosylate (XIIIb)	H_5	9.86 [b]	11.4	1.2
1,5-Dimethyl-3-phenyl-triazolium tosylate (XIIIa)	H_4	9.86 [b]	6.0	2.2
1,3-Dimethyl-4-methoxy-triazolium tosylate (XVI)	H_5	9.86 [b]	7.4	1.8
1,3-Dimethyl-4-bromo-triazolium tosylate (Ia)	H_5	6.96 [a]	23.2	452
1-Methyl-3-benzyl-4-bromo-triazolium tosylate (Ib)	H_5	6.96 [c]	10.1	1040
1-Benzyl-3-methyl-4-bromo-triazolium tosylate (IVb)	H_5	6.96 [c]	8.4	1250

[a] The rates were measured by NMR at 34°. [b] Borate buffer. [c] Phosphate buffer. [d] The bromide was used instead of the tosylate because of the low solubility of the latter. [e] Mean value for the 4- and 5-proton, since these signals coincide.

of the carbanion is coplanar with the triazole-ring and overlap with the 2*p*-orbitals therefore impossible.

Disregarding steric factors it would be reasonable to assume that the rate of bromination of a triazolium salt is proportional to the rate of deuterium exchange, since both reactions must proceed *via* the same "ylide"-anions. Hence, the relative bromonium ion acceptor properties of triazolium salts may be predicted from the exchange data presented in Table 2. According to these, the relative bromonium ion acceptor properties of 1,3-dimethyl-1,2,3-triazolium tosylate (IIIa), 1,5-dimethyl-3-phenyl-1,2,3-triazolium tosylate (XIIIa), and 1-methyl-3-phenyl-1,2,3-triazolium tosylate (IIId) should therefore be 1/1.1/22. Actually, a ratio of 1/1.5/28 was determined in the reaction of (IIIa), (XIIIa), or (IIId) with *N*-bromoacetamide in aqueous base. Likewise, it would be reasonable to assume that the rate of halonium ion abstraction of a given halosubstituted salt should be proportional to the rate of the proton abstraction of the corresponding salt with halogen replaced by hydrogen. Hence, the relative bromonium ion donor properties of triazolium salts may also be predicted from Table 2. Since the nucleophilic substitutions are rate-limiting, the ratio between products formed *via* the different routes B_1, B_2, C_1, and C_2 may yield information about the relative reactivity of halogen atoms of 1,2,3-triazolium salts towards nucleophilic substitution. The $(B_1+B_2)/(C_1+C_2)$-ratio in the reaction of (IIId) with *N*-bromoacetamide and sodium hydroxide was small, indicating that bromine in the dibromo compound (IId) is more reactive towards substitution by hydroxide ion than bromine in the monobromo compounds (Id) or (IVd). A similar observation was made in the 1,3-dimethyl triazolium salt series.[1]

The B_1/B_2 and C_1/C_2-ratio in the reaction of (IIId) with *N*-bromoacetamide and sodium hydroxide were 3.3/1 and 1/3.1, respectively. The ratios are similar to that of the exchange rates of the two heteroaromatic protons of (IIId) (Table 2). When no decomposition takes place, it therefore seems possible to predict the ratios B_1/B_2 and C_1/C_2 in the reaction between unsubstituted 1,2,3-triazolium salts (III), *N*-bromoacetamide, and sodium hydroxide by measuring the ratio between the exchange ratio of the heteroaromatic protons of (III). Further work is in progress to confirm this hypothesis.

EXPERIMENTAL

Thin layer and column chromatography were carried out as described previously.[5] NMR-spectra were obtained on Varian A-60 or HA-100 instruments. Positions of signals are given in ppm (δ-values) relative to TMS, when not otherwise stated. Deuteriochloroform was used as a solvent, unless otherwise stated. Melting points are uncorrected.

1-Benzyl-4-bromo-1,2,3-triazole. Bromine (13.5 ml) was added with stirring at room temperature to a mixture of 1-benzyl-1,2,3-triazole [2] (13.2 g), carbon tetrachloride (50 ml), water (50 ml), and sodium carbonate (10 g). After stirring for 1 h, the volume was reduced *in vacuo* to *ca.* 25 ml, and water (200 ml) was added. The solution was extracted with methylene chloride (200 ml and 50 ml). After drying, the methylene chloride was removed, leaving an orange, sticky mass, which was extracted with boiling ether (5 × 100 ml). The ether solution was filtered through activated carbon, and the solvent was removed, leaving a crystalline residue. Recrystallization from ether-hexane afforded 6.60 g (33 %) of 1-benzyl-4-bromo-1,2,3-triazole as colourless crystals, m.p. 74°. (Found: C 45.25; H 3.48; N 17.83; Br 33.78. Calc. for $C_9H_8N_3Br$: C 45.40; H 3.39; N 17.65; Br 33.57.)

Since 1-substituted 1,2,3-triazoles quaternize in 3-position,[2-4] the structure was proved by quaternization (see below) to give 1-benzyl-3-methyl-4-bromo-1,2,3-triazolium tosylate (Ib) different from the salt (IVb) prepared from benzyl tosylate and 1-methyl-4-bromo-1,2,3-triazole, the structure of which has been previously established.[7]

Preparations of quaternary salts

1-Methyl-3-benzyl-1,2,3-triazolium tosylate (IIIb) and bromide (IIIb, A=Br). 1-Benzyl-1,2,3-triazole [2] (2.03 g) and methyl tosylate (2.40 ml) were heated to 100° for 3 h. The crystal cake was crushed with 3 portions of ether (10 ml) and recrystallized from methanol-ether. Yield 4.28 g (97 %) of 1-methyl-3-benzyl-1,2,3-triazolium tosylate (IIIb), colourless crystals, m.p. 154–155°. (Found: C 58.99; H 5.69; N 11.98; S 9.12. Calc. for $C_{17}H_{19}N_3O_3S$: C 59.11; H 5.55; N 12.17; S 9.28.) (IIIb) (1.08 g), dissolved in water, was passed through a column of Amberlite IRA-400 (25 ml), prewashed with 1 N hydrobromic acid. The eluate was evaporated to dryness, and the residue was recrystallized from methanol-ether, yielding 0.75 g (94 %) of 1-methyl-3-benzyl-1,2,3-triazolium bromide (III, A=Br) as colourless crystals, m.p. 185°. (Found: C 47.45; H 5.00; N 16.49; Br 31.38. Calc. for $C_{10}H_{12}N_3Br$: C 47.26; H 4.76; N 16.53; Br 31.45.)

1,3-Dibenzyl-1,2,3-triazolium bromide (IIIc, A=Br) and tosylate (IIIc). Similarly, 1-benzyl-1,2,3-triazole [2] (2.85 g) and benzyl bromide (2.60 ml) gave, after heating to 100° for 3 h, washing with ether, and recrystallization from methanol-ether, 5.67 g (97 %) of 1,3-dibenzyl-1,2,3-triazolium bromide (IIIc, A=Br) as colourless crystals, m.p. 129–130°. (Found: C 58.43; H 4.46; N 12.65; Br 24.33. Calc. for $C_{16}H_{14}N_3Br$: C 58.55; H 4.30; N 12.79; Br 24.34.) (IIIc, A=Br) (0.74 g) dissolved in water (50 ml), was passed through a column of Amberlite IRA-400 (20 ml), prewashed with *p*-toluenesulfonic acid. The eluate was evaporated to dryness, and the residue was recrystallized from methanol-ether yielding 0.82 g (92 %) of 1,3-dibenzyl-1,2,3-triazolium tosylate (IIIc) as colourless crystals, m.p. 173–174°. (Found: C 63.61; H 5.60; N 10.70; S 7.96. Calc. for $C_{21}H_{23}N_3O_3S$: C 63.45; H 5.83; N 10.57; S 8.07.)

1-Methyl-3-phenyl-1,2,3-triazolium tosylate (IIId). Similarly, 1-phenyl-1,2,3-triazole [8] (631 mg) and methyl tosylate (0.81 ml) gave, after heating to 100° for 3 h, washing with ether, and recrystallization from methanol-ether, 1.46 g (100 %) of 1-methyl-3-phenyl-1,2,3-triazolium tosylate (IIId) as colourless crystals, m.p. 113–114°. (Found: C 58.20; H 5.11; N 12.61; S 9.86. Calc. for $C_{16}H_{17}N_3O_3S$: C 57.98; H 5.18; N 12.68; S 9.68.)

1,4-Dimethyl-3-phenyl-1,2,3-triazolium tosylate (XXVIIb). Similarly, 1-phenyl-5-methyl-1,2,3-triazole [9] (1.05 g) and methyl tosylate (1.23 ml) by heating to 100° for 3 h, washing with ether, and two reprecipitations from methanol-ether gave a brown oil. Purification required conversion to the crystalline bromide. The oil was dissolved in water and passed through Amberlite IRA-400 (50 ml) in the bromide form. Removal of the solvent and recrystallization from methanol-ether gave 1,4-dimethyl-3-phenyl-1,2,3-triazolium bromide (XXVIIb, A=Br) as colourless crystals, m.p. 96–98°. The material was dissolved in water and passed through Amberlite IRA-400 (60 ml), regenerated with *p*-toluenesulfonic acid. Removal of water and reprecipitation from methanol-ether gave 1.82 g (81 %) of 1,4-dimethyl-3-phenyl-1,2,3-triazolium tosylate (XXVIIb) as a colourless oil, which could not be induced to crystallize. (Found: C 59.34; H 5.41; N 12.32; S 9.45. Calc. for $C_{17}H_{16}N_3O_3S$: C 59.63; H 4.72; N 12.27; S 9.37.)

1,5-Dimethyl-3-phenyl-1,2,3-triazolium tosylate (XIIIa). Similarly, 1-phenyl-4-methyl-1,2,3-triazole [8] (1.75 g) and methyl tosylate (2.10 ml) by heating to 100° for 3 h, washing with ether, and recrystallization from methanol-ether gave 3.81 g (100 %) of 1,5-dimethyl-3-phenyl-1,2,3-triazolium tosylate (XXVIIa) as colourless crystals, m.p. 131–132°. (Found: C 59.46; H 4.89; N 12.27; S 9.26.)

1-Benzyl-3-methyl-4-bromo-1,2,3-triazolium tosylate (Ib). Similarly, 1-benzyl-4-bromo-1,2,3-triazole (IXb) (4.58 g) and methyl tosylate (3.70 ml) by heating to 100° for 3 h, washing with ether, and recrystallization from methanol-ether afforded 7.04 g (86 %) of 1-benzyl-3-methyl-4-bromo-1,2,3-triazolium tosylate (Ib) as colourless crystals, m.p. 191–192°. (Found: C 48.22; H 4.38; N 9.81; Br 18.66; S 7.37. Calc. for $C_{17}H_{18}N_3O_3SBr$: C 48.12; H 4.28; N 9.91; Br 18.83; S 7.56.)

1-Methyl-3-benzyl-4-bromo-1,2,3-triazolium tosylate (IVb). Similarly, 1-methyl-4-bromo-1,2,3-triazole [6] (IXa) (1.00 g) and benzyl tosylate [10] (2.86 g) by heating to 100°

for 3 h, washing with ether and ethyl acetate, and recrystallization from chloroform-ethyl acetate afforded 2.31 g (88 %) of 1-methyl-3-benzyl-4-bromo-1,2,3-triazolium tosylate (IVb) as colourless crystals, m.p. 139 – 141°. (Found: C 48.00; H 4.39; N 10.03; Br 18.72; S 7.65.)

1-Methyl-3-benzyl-4,5-dibromo-1,2,3-triazolium tosylate (IIb). Similarly, 1-methyl-4,5-dibromo-1,2,3-triazole [1] (316 mg) and benzyl tosylate [10] (651 mg) by heating to 100° for 3 h, washing with ether, and recrystallization from methanol-ether afforded 554 mg (84 %) of 1-methyl-3-benzyl-4,5-dibromo-1,2,3-triazolium tosylate (IIb) as colourless crystals, m.p. 177 – 179°. (Found: C 40.40; H 3.60; N 8.50; Br 31.95; S 6.31. Calc. for $C_{17}H_{17}N_3SBr_2$: C 40.57; H 3.41; N 8.35; Br 31.78; S 6.37.)

Reactions with aqueous base

Preparative experiments. 1-Benzyl-3-methyl-4-bromo-1,2,3-triazolium tosylate(Ib) and sodium hydroxide. (Ib) (746 mg) and 1 N sodium hydroxide (2.80 ml) were heated to reflux for 3 h. A brown oil, smelling of isonitrile, separated. The mixture was extracted with ethyl acetate (4 × 5 ml). The ethyl acetate was cautiously distilled off, leaving 167 mg of a brown oil. An NMR-spectrum indicated the presence of several compounds, none of which were identical with the triazolio-oxides (Vb), (VIb), (VIIb), or (VIIIb). The same result was found by TLC. The oil was not identified further. The aqueous solution was evaporated to dryness *in vacuo*, and the residue was extracted 5 times with boiling chloroform (10 ml). As shown by NMR, the extract contained the 1-methyl-3-benzyl-1,2,3-triazolium salt (IIIb) as a mixture of tosylate and bromide. The chloroform was removed and the residue dissolved in water and passed through Amberlite IRA-400 (7 ml), pretreated with 1 N hydrobromic acid. The water was removed, and the residue was recrystallized from methanol-ether, yielding 182 mg (41 %) of 1-methyl-3-benzyl-1,2,3-triazolium bromide (IIIb, A = Br) as colourless crystals, m.p. 169 – 170°. Further recrystallization raised the melting point to 185°. IR- and NMR-spectra proved the identity with the material prepared above.

1-Methyl-3-benzyl-4-bromo-1,2,3-triazolium tosylate (IVb) and sodium hydroxide. (IVb) (663 mg) and 1 N sodium hydroxide (2.50 ml) were heated to reflux for 3 h. A brown, isonitrile-smelling oil separated. The mixture was worked up as described in the previous experiment. The ethyl acetate extract contained 154 mg of a brown oil, identical with that described above. The chloroform extract, treated as described, gave 162 mg (41 %) of 1-methyl-3-benzyl-1,2,3-triazolium bromide (IIIb, A = Br).

1-Methyl-3-benzyl-4,5-dibromo-1,2,3-triazolium tosylate (IIb) and sodium hydroxide. (IIb) (174 mg) and 1 N sodium hydroxide (0.70 ml) were heated to reflux for 3 h. A brown, isonitrile-smelling oil separated. The mixture was worked up as described in the previous experiments. The ethyl acetate extract contained 67 mg of a brown oil, identical with that described above. The chloroform extract contained 12 mg of a yellow oil. Neither the bromo-triazolio-oxides (VIb) and (VIIb), nor the 1-methyl-3-benzyl-triazolium salt (IIIb) were present, as shown by NMR.

1-Methyl-3-benzyl-5-bromo-1,2,3-triazolio-4-oxide (VIIb) and sodium hydroxide. (VIIb) [11] (76 mg) and 1 N sodium hydroxide (0.27 ml) were heated to reflux for 3 h. The water was removed *in vacuo* and the residue was extracted 5 times with boiling chloroform (10 ml). Removal of the chloroform left the unchanged starting material in quantitative yield as colourless crystals, m.p. 122 – 123°. The identity was proved by IR- and NMR-spectra.

Spectroscopic experiments. A. 1-Benzyl-3-methyl-4-bromo-1,2,3-triazolium tosylate (Ib) (45 mg) was dissolved in 1 N aqueous potassium hydroxide (1.50 ml). After 5 min the mixture was acidified with hydrochloric acid (all triazolium salts and triazolio-oxides are stable in acid solution) and the solvent was removed *in vacuo*. The residue was dissolved in deuterium oxide. A 100 MHz NMR-spectrum, obtained in the frequency sweep mode with sodium 3-(trimethylsilyl)-propanosulfonate (DSS) as the lock signal, showed the presence of 4 CH_3-signals at δ 4.25_4, 4.33_8, 4.33_8, and 4.36_9; 4 CH_2-signals at δ 5.79_8, 5.81_0, 5.83_1, and 5.85_7; and 3 phenyl group signals (in addition to the tosylate quartet) at δ 7.51, 7.52, and 7.55. Signals corrresponding to single aromatic protons were present at δ 8.55_0 (quartet, $J_{AB} = 1.5_4$ Hz) and at δ 8.70_4 (broad singlet). In order to identify these signals, the 4 pure salts (Ib), (IIb), (IIIb), and (IVb), were added, one after the

other, to the mixture. The signals at δ 4.25_4, 5.85_7, 7.55, and, partly, that at 8.70_4 were due to the starting material (Ib). The signals at δ 4.36_9, 5.79_8, 7.51, and, partly, that at 8.70_4 were due to the isomeric salt (IVb). The signals at δ 4.33_3, 5.83_1, and 7.52 were due to 1-methyl-3-benzyl-4,5-dibromo-1,2,3-triazolium tosylate (IIb). The signals at δ 4.33_8, 5.81_0, 7.52, and 8.55_0 were due to 1-methyl-3-benzyl-1,2,3-triazolium tosylate (IIIb). The ratio between (Ib), (IIb), (IIIb), and (IVb) was 1.11/1.00/1.00/0.59.

B. Similarly, 1-methyl-3-benzyl-4-bromo-1,2,3-triazolium tosylate (IVb) (45 mg) was dissolved in 1 N potassium hydroxide (1.50 ml). After 5 min the solution was acidified, the solvent removed, the residue was dissolved in deuterium oxide, and 100 MHz NMR-spectra were obtained. The spectra indicated the presence of (Ib), (IIb), (IIIb) and (IVb) in the ratio 0.80/1.00/1.00/0.53. The compounds were identified as described above.

C. Similarly, 1-methyl-3-benzyl-4,5-dibromo-1,2,3-triazolium tosylate (27 mg) and 1-methyl-3-benzyl-1,2,3-triazolium tosylate (18 mg) were dissolved in 1 N potassium hydroxide (1.50 ml). After 5 min the solution was acidified, the solvent was removed, the residue was dissolved in deuterium oxide, and 100 MHz NMR-spectra were obtained. The spectra indicated the presence of (Ib), (IIb), (IIIb), and (IVb) in the ratio 0.79/1.00/1.00/0.31. The compounds were identified as described above.

Reactions with *N*-bromoacetamide and aqueous base

1-Methyl-3-benzyl-1,2,3-triazolium tosylate (IIIb) (464 mg), *N*-bromoacetamide (576 mg), and 1 N sodium hydroxide (5.5 ml) were kept at room temperature for 14 days. The mixture was then extracted with ethyl acetate (4 × 5 ml). Removal of the ethyl acetate gave a brown, isonitrile-smelling oil which was identical with the oily product described above as seen from NMR.

1,3-Dibenzyl-1,2,3-triazolium tosylate (IIIc). Similarly, (IIIc) (107 mg), *N*-bromoacetamide (85 mg), and 1 N sodium hydroxide (1.50 ml) were kept at room temperature for 14 days with occasional stirring. Extraction with ethyl acetate then gave the same oil as obtained above.

1-Methyl-3-phenyl-1,2,3-triazolium tosylate (IIId). A. (IIId) (522 mg) and *N*-bromoacetamide (544 mg) (molar ratio 1/2.5) were dissolved in 1 N sodium hydroxide (7.0 ml), and the mixture was kept at room temperature for 14 days. The solvent was then removed

Table 3. Spectroscopic data of 1,2,3-triazolio-4-oxides.

Compound	Infrared[a] cm^{-1}	H_5 ppm	NCH_3 ppm	NMR[b] $J_{^{13}C-H}$ Hz	CCH_3 ppm	$J_{^{13}C-H}$ Hz
1-Phenyl-3-methyl-triazolio-4-oxide (Vd)	1652	7.10	3.82	143		
1,5-Dimethyl-3-phenyl-triazolio-4-oxide (XVa)	1640		3.88	144	2.22	132
1-Phenyl-3,5-dimethyl-triazolio-4-oxide (XVb)	1647		3.80	143	2.22	131
1-Methyl-3-phenyl-5-bromo-triazolio-4-oxide (VIId)	1652		3.92	145		
1-Phenyl-3-methyl-5-bromo-triazolio-4-oxide (VId)	1658		3.85	143		

[a] IR-spectra were obtained in potassium bromide discs. [b] NMR-spectra were obtained in deuteriochloroform with TMS as an internal standard.

and the residue extracted with boiling chloroform (5 × 10 ml). Evaporation of the chloroform gave an oil which was chromatographed on silica gel (20 g) using ethyl acetate as eluent. The first fraction contained 280 mg (70 %) of 1-methyl-3-phenyl-5-bromo-1,2,3-triazolio-4-oxide (VIId) as a yellow oil, which crystallized on standing at room temperature, m.p. 98 – 102°. Recrystallization from ethyl acetate-ether raised the melting point to 106 – 108°. (Found: C 42.64; H 3.36; N 16.64; Br 31.48. Calc. for $C_9H_8N_3OBr$: C 42.54; H 3.17; N 16.53; Br 31.45.) Spectroscopic data are given in Table 3. The column was then eluted with ethyl acetate-methanol (1/1). This gave a fraction containing 96 mg (24 %) of 1-phenyl-3-methyl-5-bromo-1,2,3-triazolio-4-oxide (VId) as a yellow oil. The oil was extracted with several portions of boiling ether. Removal of the ether gave a colourless oil which crystallized on standing at room temperature, m.p. 164 – 167°. Recrystallization from ethyl acetate-ether raised the melting point to 167 – 168°. (Found: C 42.69; H 3.25; N 16.41; Br 31.41.) Spectroscopic data are given in Table 3.

B. Similarly, (IIId) (409 mg), *N*-bromoacetamide (174 mg) (molar ratio 1/1), and 1 N sodium hydroxide (5.50 ml), after standing at room temperature for 14 days, removal of the solvent, and extraction with chloroform gave an orange crystalline residue, which was extracted with ethyl acetate (4 × 10 ml). The residue was dissolved in water and passed through Amberlite IRA-400 (20 ml) regenerated with *p*-toluenesulfonic acid. Removal of the water and recrystallization from methanol-ether gave 139 mg (34 %) of starting material (IIId) as colourless crystals, m.p. 97 – 103°. The identity was confirmed by IR- and NMR-spectra. The ethyl acetate extract gave 132 mg of oil, which was purified by preparative TLC using one 20 × 40 cm plate with a 1 mm layer of silica gel and eluting 3 times with ethyl acetate. The fraction with R_F-value 0.43 contained 68 mg (22 %) of 1-methyl-3-phenyl-5-bromo-1,2,3-triazolio-4-oxide (VIId) as colourless crystals, m.p. 102 – 103°. Recrystallization from ethyl acetate-ether raised the melting point to 106 – 108°. IR- and NMR-spectra were identical with those of the material described above. The fraction with R_F-value 0.10 contained 22 mg (7 %) of 1-phenyl-3-methyl-5-bromo-1,2,3-triazolio-4-oxide (VId) as a colourless oil, which crystallized on standing, m.p. 162 – 164°. Purification as described above raised the melting point to 167 – 168°. IR- and NMR-spectra proved the identity with the material described above. The fraction with $R_F = 0$ was chromatographed using one 20 × 40 cm plate with 1 mm layer of silica gel and eluting 4 times with acetone. The fraction with R_F-value 0.25 contained 1.7 mg (0.8 %) of 1-methyl-3-phenyl-1,2,3-triazolio-4-oxide (VIII) as a yellow oil which crystallized on standing, m.p. 69 – 73°. The compound was identified by its IR- and NMR-spectra. The fraction with R_F-value 0.08 contained 5.7 mg (2.6 %) of 1-phenyl-3-methyl-1,2,3-triazolio-4-oxide (Vd) as yellow crystals, m.p. 145 – 151°. IR- and NMR-spectra proved the identity with the material prepared by dehalogenation of (VId) described below.

Spectroscopic experiments. (IIId) (31 mg) and *N*-bromoacetamide (18 mg) (molar ratio 1/1) were dissolved in 1 N sodium hydroxide (350 µl), and NMR-spectra were obtained at intervals. A methyl group signal at δ 4.48 appeared rapidly and grew at the expense of the methyl group signal at δ 4.53, due to the starting material (IIId). After 7 min (temp. 34°), the two signals were approximately equal in intensity, and further reaction of (IIId) did not take place. At this time, a peak at δ 3.98, due to the bromo-triazolio-oxide, (VIId), appeared and grew at the expense of the peak at δ 4.48. 15 min later, another peak at δ 3.85 due to the bromo-triazolio-oxide (VId) appeared and grew at the expense of the peak at δ 4.48. The reaction was complete after *ca.* two days. The bromo-triazolio-oxides (VId) and (VIId) were identified by adding, one by the other, the pure substances to the solution. When the reaction was carried out at 18°, 25 % of the starting material was converted in 73 min.

1,3-Dimethyl-1,2,3-triazolium tosylate (IIIa). Similarly, (IIIa) (19 mg), *N*-bromoacetamide (15 mg), and sodium hydroxide (400 µl) were kept at 18°. NMR-spectra indicated that 25 % of (IIIa) had reacted in the course of 2070 min to the products described previously.[1]

1,4-Dimethyl-3-phenyl-1,2,3-triazolium tosylate (XIIIb) (263 mg), *N*-bromoacetamide (214 mg), and 1 N sodium hydroxide (5.10 ml) were heated to 70° for 6 h. The water was then removed *in vacuo*, and the residue was extracted with boiling chloroform (5 × 10 ml). Removal of the chloroform and extraction with ethyl acetate left 147 mg of unchanged starting material (XIIIb) as a mixture of tosylate and bromide (NMR-spectrum). The extract was filtered through activated carbon, the solvent was removed, and the residue

was extracted with boiling ether (10 × 10 ml). The residue consisted of 33 mg of unchanged starting material. The extract contained 29 mg (20 %) of 1,4-dimethyl-3-phenyl-1,2,3-triazolio-4-oxide (XVb) as a colourless oil. Recrystallization from ether raised the melting point to 143°. (Found: C 63.62; H 6.06; N 22.11. Calc. for $C_{10}H_{11}N_2O$: C 63.49; H 5.87; N 22.21.)

1,5-Dimethyl-3-phenyl-1,2,3-triazolium tosylate (XIIIa). Similarly, (XIIIa) (331 mg), *N*-bromoacetamide (268 mg), and 1 N sodium hydroxide (6.40 ml) afforded 147 mg of unchanged starting material as a mixture of tosylate and bromide, and 44 mg (24 %) of 1,5-dimethyl-3-phenyl-1,2,3-triazolio-4-oxide (XVa) as a colourless oil, which crystallized on standing, m.p. 63 – 72°. Purification, as described above for the isomeric compound, raised the melting point to 79 – 81°. The compound is very hygroscopic, and a correct analysis could therefore not be obtained. (Found: C 58.20; H 6.24; N 20.35.)

Spectroscopic experiments. (XIIIa) (36 mg), *N*-bromoacetamide (15 mg), and 1 N sodium hydroxide (400 µl) were kept at 18°. NMR-spectra were obtained with intervals. A methyl group signal at δ 4.39, most probably due to the bromo compound (XIVa), appeared after *ca.* 1 h and grew at the expense of the *N*-methyl group signal at δ 4.30, due to the starting material (XIIIa). The two signals were equal in intensity after 1400 min. After 28 h, two peaks at δ 3.92 and 2.20, due to the triazolio-oxide (XVa), appeared and grew, the former peak at the expense of the peak at δ 4.39. After 21 days 21 % of (XVa) was present.

Dehalogenation of 1-methyl-3-phenyl-5-bromo-1,2,3-triazolio-4-oxide.[14] (VIId) (62 mg) was dissolved under nitrogen in a mixture of 4 N potassium hydroxide (0.50 ml) and methanol (0.50 ml). 5 % palladium on charcoal (Fluka, *puriss.*) (20 mg) and sodium borohydride (19 mg) were then added with stirring at room temperature. Stirring was continued for 6 h. The mixture was then filtered and the residue washed with 50 % methanol. To the filtrate, hydrochloric acid was added to pH 8. The solvents were then removed *in vacuo*, and the residue was extracted with boiling chloroform (5 × 10 ml). Evaporation of the chloroform gave 41 mg (95 %) of 1-methyl-3-phenyl-1,2,3-triazolio-4-oxide (VIIId) as colourless crystals, m.p. 88 – 92°. Recrystallization from ethyl acetate-hexane with cooling in dry ice raised the melting point to 95 – 98°. IR- and NMR-spectra were identical with those of the material described previously.[12]

Dehalogenation of 1-phenyl-3-methyl-5-bromo-1,2,3-triazolio-4-oxide (VId). Similarly, (VId) (40 mg), dissolved in 4 N potassium hydroxide (0.50 ml) and methanol (0.50 ml.) with palladium on charcoal (13 mg) and sodium borohydride (13 mg), gave 21 mg (77 %) of 1-phenyl-3-methyl-1,2,3-triazolio-4-oxide (Vd) as colourless crystals, m.p. 148 – 151°, Recrystallization from ether, as described above for 1,4-dimethyl-3-phenyl-1,2,3-triazolio-4-oxide, raised the melting point to 155 – 156°.

REFERENCES

1. Begtrup, M. and Kristensen, P. A. *Acta Chem. Scand.* **23** (1969) 2733.
2. Wiley, R. H. and Moffat, J. *J. Am. Chem. Soc.* **77** (1955) 1703.
3. Gompper, R. *Chem. Ber.* **90** (1957) 382.
4. Begtrup, M. and Pedersen, C. *Acta Chem. Scand.* **20** (1966) 1555.
5. Begtrup, M. and Pedersen, C. *Acta Chem. Scand.* **19** (1965) 2022.
6. Hüttel, R. and Welzel, G. *Ann.* **593** (1955) 382.
7. Pedersen, C. *Acta Chem. Scand.* **13** (1959) 888.
8. Bertho, A. *Ber.* **58** (1925) 861.
9. Dimroth, O. *Ber.* **35** (1902) 1029.
10. Drahowzal, F. and Klarmann, D. *Monatsh.* **82** (1951) 485.
11. Begtrup, M. and Pedersen, C. *Acta Chem. Scand.* **23** (1969) 1091.
12. Begtrup, M. and Pedersen, C. *Acta Chem. Scand.* **21** (1967) 633.
13. Begtrup, M. *To be published.*
14. Egli, R. A. *Helv. Chim. Acta* **51** (1968) 2090.

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