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Studies on Methylated 1,2,3-Triazoles

V. Preparation of 5-Substituted 1-Alkyl-4-hydroxy-1,2,3-triazoles

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5-Substituted 1-methyl-4-hydroxy-1,2,3-triazoles (VII) were prepared from 5-substituted 1-methyl-3-benzyl-1,2,3-triazolio-4-oxides (III) which, by heating with benzoyl chloride, gave 5-substituted 1-methyl-4-benzoyloxy-1,2,3-triazoles (V). Hydrolysis of these gave the title compounds (VII).

1,3-Dibenzyl-1,2,3-triazolio-4-oxide (IIId) with benzoyl chloride yielded 1-benzyl-4-benzoyloxy-1,2,3-triazole (Vd) and 1-benzyl-5-benzoyloxy-1,2,3-triazole (VId). The former by hydrolysis gave (VIId).

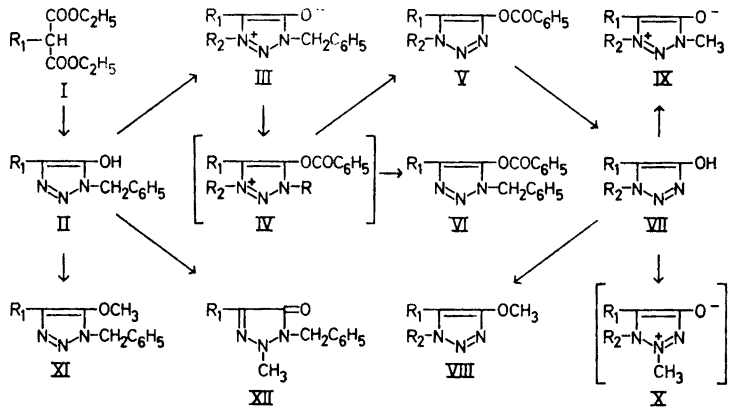
The hydroxytriazoles (VII) with diazomethane gave *O*-methylated and *N*-methylated products (VIII) and (IX).

The preparation of 1-methyl-4-hydroxy-1,2,3-triazole (VIIe) was described in a previous paper.[1] 1-Benzyl-5-hydroxy-1,2,3-triazole with methyl iodide gave 1-methyl-3-benzyl-1,2,3-triazolio-4-oxide (IIIe) which by heating with benzoyl chloride, *via* the quaternary salt (IVe, R=$C_6H_5CH_2$), yielded 1-methyl-4-benzoyloxy-1,2,3-triazole (Ve). Hydrolysis of the latter compound gave 1-methyl-4-hydroxy-1,2,3-triazole (VIIe).

This method has now been used to prepare 1-methyl-4-hydroxy-1,2,3-triazoles with substituents in the 5 position. Besides, 1-benzyl-4-hydroxy-1,2,3-triazole (VIId) has been synthesized and the method therefore makes 5-substituted 1-alkyl-4-hydroxy-1,2,3-triazoles (VII) readily available.

The starting materials, the 4-substituted 1-benzyl-5-hydroxy-1,2,3-triazoles (II), were prepared from benzyl azide and substituted malonic esters in the presence of sodium alkoxide. Thus diethyl phenylmalonate (Ib), dry sodium ethoxide, and benzyl azide yielded 34 % of 1-benzyl-4-phenyl-5-hydroxy-1,2,3-triazole (IIb). The reaction probably follows the same course as the reaction between diethyl malonate and benzyl azide described by Dimroth.[2]

When the sodium salt of the hydroxytriazole (IIb) was heated with an excess of methyl iodide three isomeric products were obtained. The main product (68 % yield) was 1-methyl-3-benzyl-5-phenyl-1,2,3-triazolio-4-oxide (IIIb); the infrared spectrum of this product showed a carbonyl absorption at 1640 cm^{-1}, characteristic of triazolio-oxides.[3] The second product showed



	R_1	R_2
a:	CH_3	CH_3
b:	C_6H_5	CH_3
c:	Br	CH_3
d:	H	$CH_2C_6H_5$
e:	H	CH_3

no carbonyl absorption and must therefore be 1-benzyl-4-phenyl-5-methoxy-1,2,3-triazole (XIb). The third product absorbed at 1645 cm^{-1} and, in analogy with earlier results,[3] it is probably 1-benzyl-2-methyl-4-phenyl-1,2,3-triazolone-5 (XIIb).

By heating the triazolio-oxide (IIIb) with excess benzoyl chloride 1-methyl-5-phenyl-4-benzoyloxy-1,2,3-triazole (Vb) was obtained. Hydrolysis of the latter with sodium hydroxide gave 1-methyl-5-phenyl-4-hydroxy-1,2,3-triazole (VIIb). The structure of (VIIb) was ascertained by methylation with diazomethane which gave 1-methyl-5-phenyl-4-methoxy-1,2,3-triazole (VIIIb) and 1,3-dimethyl-5-phenyl-1,2,3-triazolio-4-oxide (IXb), both of which have been described previously.[3] No other methylation products could be detected.

Methylation of 1-benzyl-4-methyl-5-hydroxy-1,2,3-triazole (IIa) with diazomethane gave a mixture of the triazolio-oxide (IIIa), the methoxy triazole (XIa), and the triazolone (XIIa). The structures of these products were determined by infrared spectroscopy (Table 1), analogous to the results described above. The sodium salt of (IIa), when treated with methyl iodide, gave the triazolio-oxide (IIIa) as the only product. When (IIIa) was heated with benzoyl chloride in the presence of diisopropylethylamine [4] 1,5-dimethyl-4-benzoyloxy-1,2,3-triazole (Va) was obtained. Hydrolysis of the latter gave 1,5-dimethyl-4-hydroxy-1,2,3-triazole (VIIa). Methylation of (VIIa) with diazomethane gave a mixture of the triazolio-oxide (IXa) and the methoxy compound (VIIIa). The latter compound was rearranged to (IXa) by treatment with methyl iodide in agreement with previous results.[3,5]

In analogy to the method described above 1-methyl-5-bromo-4-hydroxy-1,2,3-triazole (VIIc) was readily prepared, *via* its 4-*O*-benzoyl derivative

Table 1. NMR spectra at 60 MHz in deuteriochloroform with TMS as an internal standard and infrared absorptions of carbonyl groups.

	Infrared cm^{-1}	NMR											
		CH ppm	CH_2 ppm	ppm	OCH_3 ppm	$J_{^{13}C-H}$ Hz	NCH_3 ppm	$J_{^{13}C-H}$ Hz	NCH_3 ppm	$J_{^{13}C-H}$ Hz	CCH_3 ppm	$J_{^{13}C-H}$ Hz
Triazolio-4-oxides												
III a	1628			5.21			3.80	143			2.20	131
b	1640			5.30			4.01	144				
c	1630			5.25			3.90	145				
d	1636	6.54	5.24	5.20								
e [1]	1646	6.66		5.20			3.80	144				
IX a	1630—1640						3.89	143	3.63	142	2.17	131
b [3]	1630						4.00	144	3.72	143		
c [5]	1640						3.97	144	3.77	143		
d	1640	6.72		5.28					3.61	140		
e [7]	1645	6.67					3.95	143	3.67	142		
5-Triazolones												
XII a	1672			5.10					3.28	142	2.23	130
b	1645			5.18					3.47	143		
d [3]	1660	7.14		5.18					3.51	144		
Methoxy-triazoles												
XI a				5.32	3.83	147					2.37	130
b				5.43	3.63	148						
d [3]		7.10		5.32	3.90	148						
VIII a					4.04	146	3.90	142			2.19	130
b [3]					4.09	147	4.03	142				
c					4.10	148	4.00	144				
d				5.40	3.82	147						
e [6]		7.15			3.95	146	4.03	142				
Benzoyloxy-triazoles												
V a	1744						3.89	143			2.16	132
b	1748						4.07	143				
c	1750						4.06	143				
d	1741	7.81		5.53								
e	1735	7.88					4.10	143				

(Vc), from 1-methyl-3-benzyl-5-bromo-1,2,3-triazolio-4-oxide (IIIc). The latter was obtained in high yield by bromination of (IIIe). Methylation of (VIIc) with diazomethane gave two products one of which was 1,3-dimethyl-5-bromo-1,2,3-triazolio-4-oxide (IXc), identical with the material prepared by bromination of 1,3-dimethyl-1,2,3-triazolio-4-oxide (IXe).[5] The other methylation product was assumed to be the 4-methoxy compound (VIIIc) since it showed no carbonyl absorption in infrared. Neither (VIIIc) nor 1-methyl-5-phenyl-4-methoxy-1,2,3-triazole (VIIIb)[3] could be induced to react with methyl iodide. In contrast to this 1-methyl-4-methoxy-1,2,3-triazole (VIIIe)[5] and its 5-methyl analogue (VIIIa) (see above), rearranged to the isomeric triazolio-oxides (IXe) and (IXa), respectively, when treated with methyl iodide. The rearrangement probably proceeds *via* quaternary salts as found previously.[3,5] These results indicate that 1-methyl-4-methoxy-1,2,3-triazoles do not react with methyl iodide when substituted in the 5-position with electron-withdrawing groups.

The triazolio-oxides which have been investigated in the present and the previous paper[1] have been 1-methyl-3-benzyl-1,2,3-triazolio-4-oxides and they have all lost benzyl chloride exclusively, on treatment with benzoyl chloride. This could be due either to the position of the benzyl group or to the fact that this group is a better leaving group than the methyl group. In order to investigate this the behaviour of 1,3-dibenzyl- and 1,3-dimethyl-1,2,3-triazolio-4-oxide, (IIId) and (IXe), towards benzoyl chloride was investigated.

Treatment of 1,3-dibenzyl-1,2,3-triazolio-4-oxide (IIId) with benzoyl chloride gave a mixture of the previously described 1-benzyl-5-benzoyloxy-1,2,3-triazole (VId)[1] and 1-benzyl-4-benzoyloxy-1,2,3-triazole (Vd). The latter by hydrolysis gave 1-benzyl-4-hydroxy-1,2,3-triazole (VIId), the structure of which was determined by methylation with diazomethane which gave two products. One of these products was 1-benzyl-3-methyl-1,2,3-triazolio-4-oxide (IXd), identical with the compound obtained by treatment of 1-methyl-4-methoxy-1,2,3-triazole (VIIIe) with benzyl iodide. The second methylation product is probably 1-benzyl-4-methoxy-1,2,3-triazole (VIIId) since it showed no carbonyl absorption in infrared and since it, by treatment with methyl iodide, gave (IXd).

Reaction of 1,3-dimethyl-1,2,3-triazolio-4-oxide (IXe) with benzoyl chloride gave 1-methyl-4-benzoyloxy-1,2,3-triazole (Ve)[1] and none of the isomeric 1-methyl-5-benzoyloxy-1,2,3-triazole. This indicates that the alkyl group adjacent to the benzoyloxy group in the quaternary intermediate (IV) is the most labile and that the other alkyl group at N-3 is only split off when it is a good leaving group, such as the benzyl group.

In Table 1 infrared and NMR data of a number of 1,2,3-triazole derivatives are given. Included in the table are $^{13}C-H$ coupling constants of all methyl groups. Whereas it is possible to identify $-C-CH_3$ groups on the basis of δ-values, these cannot be used to distinguish between $-O-CH_3$ and $-N-CH_3$ groups. However, by measuring $^{13}C-H$ coupling constants the latter two types of methyl groups may be identified unambiguously.

EXPERIMENTAL

Thin layer and column chromatography was carried out as described previously.[6] NMR spectra were obtained on a Varian A-60 instrument. All evaporations were performed *in vacuo* at 60°, unless otherwise stated.

Preparation of 1-benzyl-5-hydroxy-1,2,3-triazoles

1-Benzyl-4-phenyl-5-hydroxy-1,2,3-triazole (IIb). A mixture of dry sodium ethoxide (prepared from 7.0 g of sodium) and diethyl phenylmalonate (19.3 ml) was cooled in an ice-salt bath and benzyl azide (12.5 ml) was added. The mixture was kept for ½ h in the ice-salt bath and then for ½ h at room temperature. It was finally heated to reflux for 4 h and then evaporated to dryness in a 90° bath. The residue was dissolved in water (100 ml). The brown oil which separated on standing was removed and the aqueous phase was extracted with methylene chloride (3 × 25 ml), filtered through activated carbon and acidified with conc. hydrochloric acid to pH 1. The colourless, crystalline precipitate was filtered off and washed with water (100 ml) and ether (600 ml). Yield 8.62 g (34 %), m.p. 202.5° (decomp.). Recrystallization from dimethyl formamide-water raised the melting point to 208° (decomp.). (Found: C 71.57; H 5.14; N 16.93. Calc. for $C_{15}H_{13}N_3O$: C 71.70; H 5.22; N 16.72).

1-Benzyl-4-methyl-5-hydroxy-1,2,3-triazole (IIa). The reaction between diethyl methylmalonate (17.0 ml) and benzyl azide (12.5 ml) in the presence of dry sodium ethoxide, prepared from 7.0 g of sodium, was carried out by the procedure described above. By acidification the hydroxytriazole (IIa) separated as a brown oil which was isolated. The aqueous phase was extracted with methylene chloride (3 × 25 ml) and the extracts were combined with the first isolated hydroxytriazole. The solution was dried and filtered through activated carbon. Evaporation of the solvent yielded a brownish oil which was extracted with five 15 ml portions of boiling ether. The oily residue weighed 19.2 g (51 %). The product was first recrystallized from chloroform-ethyl acetate and then from water, colourless crystals, m.p. 136°. (Found: C 63.66; H 5.78; N 22.05. Calc. for $C_{10}H_{11}N_3O$: C 63.49; H 5.87; N 22.21).

Preparation of 1,2,3-triazolio-4-oxides

1 equivalent of sodium hydroxide was dissolved by heating in a 30 % suspension of the 5-hydroxy-1,2,3-triazole in methanol. An equal volume of methyl iodide was added and the mixture was refluxed for 5 h. The solvent was removed and the residue was extracted several times with boiling chloroform. The chloroform solution was washed with saturated aqueous sodium thiosulfate and then with water. The solution was dried and filtered through activated carbon. Evaporation of the solvent yielded the crude triazolio-oxide which was purified as described in the following.

1,5-Dimethyl-3-benzyl-1,2,3-triazolio-4-oxide (IIIa). In this way 1-benzyl-4-methyl-5-hydroxy-1,2,3-triazole (IIa) (9.57 g) yielded 9.10 g (77 %) of (IIIa) as a brownish oil which crystallized when kept for 3 days at room temperature. Recrystallization from ethyl acetate with cooling in dry ice yielded the pure product as colourless crystals, m.p. 87°. The compound was very hygroscopic and a correct analysis could therefore not be obtained. (Found: C 62.34; H 6.60; N 19.86. Calc. for $C_{11}H_{13}N_3O$: C 65.00; H 6.45; N 20.67).

1,3-Dibenzyl-1,2,3-triazolio-4-oxide (IIId). By the same procedure 1-benzyl-5-hydroxy-1,2,3-triazole (IId) [7] (6.40 g), when treated with benzyl chloride (4.6 ml) in methanol containing 1 equivalent of sodium hydroxide, gave 9.97 g (100 %) of (IIId) as a brownish oil which crystallized on standing at room temperature, m.p. 59–69°. Two recrystallizations from ethyl acetate-hexane followed by two recrystallizations from ether with cooling in dry ice raised the melting point to 87–90°. The compound is very hygroscopic. (Found: C 72.51; H 5.80; N 15.91. Calc. for $C_{16}H_{15}N_3O$: C 72.43; H 5.70; N 15.84).

1-Methyl-3-benzyl-5-phenyl-1,2,3-triazolio-4-oxide (IIIb). By the procedure described above 1-benzyl-4-phenyl-5-hydroxy-1,2,3-triazole (IIb) (3.93 g) yielded 4.28 g of a colourless

oil which crystallized on standing. An NMR-spectrum showed the presence of 3 isomeric compounds. The product was recrystallized twice from ethyl acetate-hexane with cooling in dry ice. The resulting semi-crystalline material was then extracted repeatedly with boiling ether. The ether solution was concentrated to 100 ml and crystallized by cooling in dry ice thereby giving 2.82 g (68 %) of 1-methyl-3-benzyl-5-phenyl-1,2,3-triazolio-4-oxide (IIIb) m.p. 80–81°. (Found: C 72.29; H 5.91; N 15.76. Calc. for $C_{16}H_{15}N_3O$: C 72.43; H 5.70; N 15.84).

The combined mother liquors contained the two other isomers which were separated by chromatography on a column of silica gel (100 g) using benzene-ether (4:1) as eluent. The first fraction contained 472 mg (11 %) 1-benzyl-4-phenyl-5-methoxy-1,2,3-triazole (XIb) as a colourless oil which could not be induced to crystallize. Two reprecipitations from ether-hexane gave the pure compound. (Found: C 72.40; H 5.78; N 15.63). The second fraction to leave the column contained 675 mg (16 %) of 1-benzyl-2-methyl-4-phenyl-1,2,3-triazolone-5 (XIIb) as a colourless oil which could not be induced to crystallize. Two reprecipitations from ether-hexane yielded the pure compound which crystallized on standing at room temperature for 3 weeks, m.p. 80–83°. (Found: C 72.29; H 5.81; N 15.70).

1-Methyl-3-benzyl-5-bromo-1,2,3-triazolio-4-oxide (IIIc). 1-Methyl-3-benzyl-1,2,3-triazolio-4-oxide (IIIe) (6.01 g) [1] was dissolved in chloroform (60 ml) and with stirring and cooling in an ice-salt bath a solution of bromine (2.00 ml) in chloroform (20 ml) was added during 1 h. In order to remove excess bromine the mixture was evaporated to dryness in a 40° bath. The oily residue was then dissolved in chloroform (100 ml) and the solution was washed with 20 % aqueous sodium carbonate (3 × 8 ml) and with water (3 × 10 ml). The chloroform solution was dried and filtered through activated carbon. Removal of the solvent yielded 7.68 g (90 %) of 1-methyl-3-benzyl-5-bromo-1,2,3-triazolio-4-oxide (IIIc) as reddish crystals, m.p. 107–111°. Recrystallization from ethyl acetate-hexane and then from ethyl acetate with cooling in dry ice raised the melting point to 127–128°. (Found: C 44.82; H 3.91; N 15.60; Br 29.66. Calc. for $C_{10}H_{10}N_3OBr$: C 44.79; H 3.76; N 15.68; Br 29.81).

Preparation of 1-methyl-4-benzoyloxy-1,2,3-triazoles

1,5-Dimethyl-4-benzoyloxy-1,2,3-triazole (Va). A. Crude 1,5-dimethyl-3-benzyl-1,2,3 triazolio-4-oxide (IIIa) (6.00 g) and benzoyl chloride (36 ml) was heated to 115° for 90 min. After cooling hexane (75 ml) was added and the brown oil was washed with five 30 ml portions of hexane and then purified by column chromatography on silica gel (150 g) eluting with benzene-ether (4:1). Two minor fractions were discarded. The third fraction contained 2.39 g (37 %) of 1,5-dimethyl-4-benzoyloxy-1,2,3-triazole (Va) as an oil which crystallized on standing, m.p. 85–88°. Recrystallization from ethanol with cooling in dry ice raised the melting point to 89–90°. (Found: C 61.06; H 5.24; N 19.21. Calc. for $C_{11}H_{11}N_3O_2$: C 60.81; H 5.10; N 19.34).

B. Crude (IIIa) (3.95 g), benzoyl chloride (24 ml), and diisopropylethylamine (3.4 ml) was heated to 115° for 90 min. After cooling diisopropylethylamine hydrochloride (1.22 g) was filtered off and washed with benzene (50 ml). The combined filtrate and washings were distilled at 1 mm in order to remove benzene, diisopropylethylamine, and benzoyl chloride. Hexane (200 ml) was added to the residue and the mixture was kept over night at −20°. The precipitated brownish oil was purified by column chromatography as described above. The first fraction to leave the column contained 1.17 g of an oily material which was not identified further. The next fraction contained 1,5-dimethyl-4-benzoyloxy-1,2,3-triazole (Va) (3.40 g) (80 %) as an oil which crystallized on standing, m.p. 42–78°. Recrystallization from ethanol as described above yielded the pure compound, m.p. 89–90°.

1-Benzyl-4-benzoyloxy-1,2,3-triazole (Vd). Crude 1,3-dibenzyl-1,2,3-triazolio-4-oxide (IIId) (9.30 g) and benzoyl chloride (35 ml) was heated to 115° for 90 min. Hexane (350 ml) was then added and the mixture was allowed to stand over night at −20°. The crystalline precipitate was filtered off and washed with ether. Yield 7.50 g. The material was purified by column chromatography on silica gel (200 g) using benzene-ether (4:1) as eluent. The first fraction contained 4.24 g (43 %) of 1-benzyl-4-benzoyloxy-1,2,3-

triazole (Vd) as colourless crystals, m.p. 118°. Recrystallization from ethanol did not raise the melting point. (Found: C 68.66; H 4.84; N 15.17. Calc. for $C_{16}H_{13}N_3O_2$: C 68.80; H 4.70; N 15.04). The second fraction contained a mixture of (Vd) and 1-benzyl-5-benzoyloxy-1,2,3-triazole (VId) (216 mg). The third fraction contained 1.56 g (16 %) of 1-benzyl-5-benzoyloxy-1,2,3-triazole (VId), m.p. 105–106°. Recrystallization from ethanol raised the melting point to 111°. Melting point, infrared and NMR spectra proved the indentity with the material described previously.[1]

1-Methyl-5-phenyl-4-benzoyloxy-1,2,3-triazole (Vb). Crude 1-methyl-3-benzyl-5-phenyl-1,2,3-triazolio-4-oxide (IIIb) (7.69 g) and benzoyl chloride (36 ml) was heated to 115° for 90 min. (The addition of diisopropylethylamine did not improve the yield). After cooling hexane (75 ml) was added and the mixture was allowed to stand at −20° over night. The mother liquor was decanted off and the oily residue extracted 6 times with 50 ml portions of hexane. The residue was dissolved in boiling ethanol (20 ml). By cooling a colourless crystalline product precipitated. Filtration and washing with hexane yielded 4.87 g (60 %), m.p. 62–64°. Recrystallization from chloroform-hexane raised the melting point to 117–118°. (Found: C 68.66; H 4.73; N 15.07. Calc. for $C_{16}H_{13}N_3O_2$: C 68.80; H 4.70; N 15.04).

1-Methyl-4-benzoyloxy-1,2,3-triazole (Ve) from 1,3-dimethyl-1,2,3-triazolio-4-oxide (IXe). 1,3-Dimethyl-1,2,3-triazolio-4-oxide [6] (3.64 g) and benzoyl chloride (8.0 ml) was heated to 115° for 90 min. The homogeneous solution, which was first formed deposited colourless crystals (possibly the intermediate, quaternary salt (IVe, R=CH_3)); the crystals then slowly went into solution. After cooling, hexane (80 ml) was added and the mixture was kept over night at −20°. The precipitate was filtered off and washed with hexane. Recrystallization from ethanol (14 ml) with cooling in dry ice yielded 2.93 g (45 %) of 1-methyl-4-benzoyloxy-1,2,3-triazole (Ve) as colourless crystals, m.p. 121–122°. The melting point and an infrared spectrum were identical with those of the material described previously.[1]

To the ethanolic mother liquor acetone (20 ml) was added. The precipitate was filtered off and washed with cold acetone and hexane. Yield 0.70 g (15 %) of colourless crystals, m.p. 149–151°. The infrared spectrum was identical with that of the hydrochloride of 1,3-dimethyl-1,2,3-triazolio-4-oxide.[6] Thin layer chromatography and NMR-spectroscopy showed that 1-methyl-5-benzoyloxy-1,2,3-triazole [8] was not present in the mother liquor.

1-Methyl-5-bromo-4-benzoyloxy-1,2,3-triazole (Vc). 1-Methyl-3-benzyl-5-bromo-1,2,3-triazolio-4-oxide (IIIc) (7.10 g) and benzoyl chloride (28 ml) was heated to 115° for 90 min. Hexane (200 ml) was then added and the mixture was kept over night at −20°. The red crystalline precipitate was filtered off and washed with hexane. Yield 5.18 g, m.p. 122–125°. Recrystallization from ethanol (40 ml) with cooling in dry ice gave 4.03 g (54 %) of 1-methyl-5-bromo-4-benzoyloxy-1,2,3-triazole (Vc) as colourless crystals, m.p. 137–138°. (Found: C 42.68; H 3.04; N 14.78; Br 28.53. Calc. for $C_{10}H_8N_3O_2Br$: C 42.58; H 2.86; N 14.89; Br 28.33).

Preparation of 1-alkyl-4-hydroxy-1,2,3-triazoles

1,5-Dimethyl-4-hydroxy-1,2,3-triazole (VIIa). 1,5-Dimethyl-4-benzoyloxy-1,2,3-triazole (Va) (2.39 g) and 2.02 equivalents of aqueous 1 N sodium hydroxide was refluxed for 90 min. The mixture was then acidified with conc. hydrochloric acid and cooled to 0°. The precipitate which consisted of benzoic acid was filtered off and washed 3 times with 10 ml of ice-cold water. The combined filtrate and washings were evaporated to dryness and the residue was extracted 5 times with dry acetone. The extract was evaporated and the residue was extracted 3 times with 10 ml of chloroform. The chloroform solution was filtered through activated carbon and the solvent was removed. The residue was recrystallized twice from chloroform-hexane yielding 0.94 g (76 %) of 1,5-dimethyl-4-hydroxy-1,2,3-triazole (VIIa) as colourless crystals, m.p. 170°. (Found: C 42.38; H 6.20; N 37.09. Calc. for $C_4H_7N_3O$: C 42.46; H 6.24; N 37.16).

1-Benzyl-4-hydroxy-1,2,3-triazole (VIId). By the same procedure 1-benzyl-4-benzoyloxy-1,2,3-triazole (Vd), after hydrolysis and acidification with hydrochloric acid gave a colourless, crystalline precipitate which was filtered off, washed with ice-cold water (2×10 ml) and, after drying, with ether (2×100 ml). The residue consisted of

1-benzyl-4-hydroxy-1,2,3-triazole (VIId), colourless crystals, m.p. 134°, yield 1.92 g (74 %). Recrystallization from chloroform-hexane did not raise the melting point. (Found: C 61.86; H 5.31; N 23.89. Calc. for $C_9H_9N_3O$: C 61.70; H 5.18; N 23.98).

1-Methyl-5-phenyl-4-hydroxy-1,2,3-triazole (VIIb). By the same procedure 1-methyl-5-phenyl-4-benzoyloxy-1,2,3-triazole (Vb) (3.80 g), gave a crystalline precipitate which, after washing with water and ether, was extracted with chloroform (5 × 10 ml). Evaporation of the chloroform gave 1.02 g (43 %) of (VIIb) as colourless crystals, m.p. 171—173°. Recrystallization from ethyl acetate-hexane raised the melting point to 173°. (Found: C 61.91; H 5.24; N 24.22. Calc. for $C_9H_9N_3O$: C 61.70; H 5.18; N 23.98).

1-Methyl-5-bromo-4-hydroxy-1,2,3-triazole (VIIc). By the same procedure 1-methyl-5-bromo-4-benzoyloxy-1,2,3-triazole (Vc) (1.83 g) gave a crystalline precipitate which was washed with water (2 × 10 ml) and ether (5 × 15 ml). The residue consisted of 1-methyl-5-bromo-4-hydroxy-1,2,3-triazole (VIIc) as colourless crystals, m.p. 132° (decomp.). Recrystallization from ethanol raised the melting point to 137° (decomp.). (Found: C 20.34; H 2.50; N 23.72; Br 45.03. Calc. for $C_3H_4N_3OBr$: C 20.24; H 2.27; N 23.61; Br 44.90).

Methylations

All methylations with diazomethane were carried out by the procedure described previously.[6] The crude products were worked up as follows.

1,5-Dimethyl-4-hydroxy-1,2,3-triazole. Methylation of 1,5-dimethyl-4-hydroxy-1,2,3-triazole (VIIa) (550 mg) gave 581 mg of a yellow oil which was chromatographed on a column of silica gel (40 g). Elution with ethyl acetate gave 113 mg (18 %) of colourless oil which crystallized on cooling. Recrystallization from ether-hexane yielded pure 1,5-dimethyl-4-methoxy-1,2,3-triazole (VIIIa), m.p. 33—35°. (Found: C 47.38; H 7.26; N 32.91. Calc. for $C_5H_9N_3O$: C 47.23; H 7.13; N 33.05). Elution of the column with methanol gave a second fraction which contained 491 mg (79 %) of a colourless oil. Recrystallization from ethyl acetate with cooling in dry ice gave pure 1,3,5-trimethyl-1,2,3-triazolio-4-oxide (IXa), m.p. 62—63°. The compound is very hygroscopic and a correct analysis could therefore not be obtained. (Found: C 44.18; H 7.43; N 30.78).

1-Benzyl-4-hydroxy-1,2,3-triazole (VIId). Methylation of (VIId) (1.72 g) gave 1.93 g of a colourless oil which was chromatographed on a column of silica gel (50 g). Elution with ethyl acetate gave 0.61 g (32 %) of 1-benzyl-4-methoxy-1,2,3-triazole (VIIId) as a yellow oil which crystallized on standing, m.p. 51—53°. Two recrystallizations from ethyl acetate gave colourless crystals, m.p. 56°. (Found: C 63.47; H 5.80; N 22.11. Calc. for $C_{10}H_{11}N_3O$: C 63.49; H 5.87; N 22.21). After collection of the methoxytriazole the column was eluted with methanol and a fraction was obtained which contained 1.41 g (75 %) of a yellow oil which crystallized on standing. Recrystallization from ethyl acetate-hexane and then from ether with cooling in dry ice gave pure 1-benzyl-3-methyl-1,2,3-triazolio-4-oxide (IXd) as colourless crystals, m.p. 87—90°. The compound is very hygroscopic and a correct analysis could not be obtained. (Found: C 60.70; H 6.20; N 21.46). Melting point, NMR and infrared spectra showed that the compound was identical with the triazolio-oxide, prepared as described below, from 1-methyl-5-methoxy-1,2,3-triazole (VIIIe).

1-Methyl-5-phenyl-4-hydroxy-1,2,3-triazole. Methylation of (VIIb) (596 mg) gave 644 mg of crude product which was chromatographed on a column of silica gel (40 g). Elution with ethyl acetate gave 264 mg (42 %) of a yellow oil which crystallized on cooling, m.p. 63—64°. Recrystallization from a mixture of ether and hexane (1:1) with cooling in dry ice raised the melting point to 77°. Melting point, infrared and NMR spectra were identical with those of 1-methyl-5-phenyl-4-methoxy-1,2,3-triazole (VIIIb).[3] Subsequent elution of the column with methanol gave 505 mg of a colourless, hygroscopic oil which crystallized on standing, m.p. 54—95°. Recrystallization from ethyl acetate with cooling in dry ice raised the melting point to 72—75°. Melting point, infrared and NMR spectra were identical with those of 1,3-dimethyl-5-phenyl-1,2,3-triazolio-4-oxide (IXb).[3]

1-Methyl-5-bromo-4-hydroxy-1,2,3-triazole. Methylation of (VIIc) (205 mg) gave 261 mg of a colourless, semicrystalline material which was chromatographed on a column of silica gel (30 g). Elution with ethyl acetate gave 90 mg (41 %) of colourless crystals, m.p. 99—102°. Recrystallization from ether with cooling in dry ice gave pure 1-methyl-5-

bromo-4-methoxy-1,2,3-triazole (VIIIc), m.p. 105—107°. (Found: C 25.19; H 3.24; N 21.98; Br 41.23. Calc for $C_4H_6N_3OBr$: C 25.02; H 3.15; N 21.89; Br 41.62). After collection of the methoxytriazole the column was eluted with methanol. This gave a second fraction which contained 134 mg (63 %) of 1,3-dimethyl-5-bromo-1,2,3-triazolio-4-oxide (IXc), m.p. 132—136°. Recrystallization from methanol-ether raised the melting point to 141°. The material was identical with the bromo-triazolio-oxide described previously.[5]

1-Benzyl-4-methyl-5-hydroxy-1,2,3-triazole. Methylation of (IIa) (647 mg) yielded 748 mg of a yellow oil which was extracted with boiling ether (5 × 50 ml). The combined extract was concentrated to *ca.* 50 ml and cooled in dry ice giving 496 mg (72 %) of colourless crystals, m.p. 81—82°. Recrystallization from ethyl acetate with cooling in dry ice gave pure 1-benzyl-3,5-dimethyl-1,2,3-triazolio-4-oxide (IIIa), m.p. 87°, identical with the product described above.

The material in the mother liquour was chromatographed on a column of silica gel (20 g). Elution with ether gave 103 mg (15 %) of a colourless oil. Two reprecipitations from ether-hexane yielded 1-benzyl-4-methyl-5-methoxy-1,2,3-triazole (XIa), m.p. 48—49°. (Found: C 64.91; H 6.53; N 20.89. Calc. for $C_{11}H_{13}N_3O$: C 65.00; H 6.45; N 20.67). Elution with ethyl acetate gave 85 mg (12 %) of an oil which could not be induced to crystallize. Two reprecipitations from ether-hexane yielded the pure 1-benzyl-2,4-dimethyl-1,2,3-triazolone-5 (XIIa). (Found: C 64.12; H 6.60; N 19.63).

Rearrangements

1-Benzyl-4-methoxy-1,2,3-triazole. (VIIId) (39 mg) was dissolved in a mixture of deuteriochloroform (0.50 ml) and methyl iodide (0.10 ml) in an NMR sample tube. The mixture was kept at room temperature and NMR spectra were taken at intervals. After 12 h the signals corresponding to the quaternary intermediate 1-benzyl-3-methyl-4-methoxy-1,2,3-triazolium iodide and the signals due to 1-benzyl-3-methyl-1,2,3-triazolio-4-oxide (IXd) could be detected (δ-values are given in Table 1). Later the signals of the triazolio-oxide (IXd) grew at the expense of the methoxy compound (VIIId). The reaction was completed after 60 days. The solvent was removed leaving the crude triazolio-oxide as a red oil which was purified by column chromatography on silica gel (20 g) using methanol as eluent. Two fractions were obtained. The first fraction contained a small amount of a yellow, semi-solid mass which was not identified further. The second fraction contained 40 mg (100 %) of pure 1-benzyl-3-methyl-1,2,3-triazolio-4-oxide as a colourless oil which crystallized on standing. The material was identical with the compound formed by the reaction of 1-methyl-5-methoxy-1,2,3-triazole with benzyl iodide (see below).

1-Methyl-5-methoxy-1,2,3-triazole [6] (87 mg) and benzyl iodide (247 mg) were dissolved in deuteriochloroform (0.50 ml) and kept at room temperature; NMR spectra were taken at intervals. After a few minutes the signals corresponding to the quaternary intermediate 1-benzyl-3-methyl-4-methoxy-1,2,3-triazolium iodide and the signals due to 1-benzyl-3-methyl-1,2,3-triazolio-4-oxide (IXd) could be detected. The liberated methyl iodide could be seen. Later the signals of the triazolio-oxide (IXd) grew at the expense of the starting material. The reaction was completed after 20 days. The solvent was then removed and the residue was chromatographed on a column of silica gel (20 g) using methanol as eluant. Two fractions were collected. The first fraction contained a red, iodine containing oil which was not identified further. The second fraction contained 104 mg (71 %) of pure 1-benzyl-3-methyl-1,2,3-triazolio-4-oxide (IXd) as an oil which crystallized on standing. Infrared and NMR spectra showed that the material was identical with the triazolio-oxide obtained by methylation of 1-benzyl-4-hydroxy-1,2,3-triazole (VIId) (see above).

1,5-Dimethyl-4-methoxy-1,2,3-triazole. A solution of (VIIIa) in deuteriochloroform and methyl iodide was allowed to stand at room temperature. After 30 days the NMR spectra showed that no reaction had taken place. The methoxy-triazole (VIIIa) (12 mg) was then dissolved in methyl iodide (3.0 ml) and heated to reflux for 8 h. Removal of the solvent left 10 mg (83 %) of 1,3,5-trimethyl-1,2,3-triazolio-4-oxide (IXa). Infrared

and NMR spectra proved the identity with the triazolio-oxide obtained by methylation of 1,5-dimethyl-4-hydroxy-1,2,3-triazole (VIIa) (see above).

1-Methyl-5-bromo-4-methoxy-1,2,3-triazole (VIIIc) did not react with methyl iodide at room temperature or by heating to reflux for 8 h.

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