# Preparation and spectral properties of tetrazoles

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Preparation of 1,5-disubstituted tetrazoles by the reaction of symmetrically substituted carbodiimides with azoimide is reported. Infrared, ultraviolet, $^1$H-n.m.r., and mass spectra of the synthesized compounds are discussed.

Описан синтез 1,5-дизамещенных тетразолов реакцией симметрически замещенных карбодиимидов с азоимидом и обсуждены ИК, Уф, $^1$H-ЯМР и масс-спектры синтезированных соединений.

In 1922 *Stollé* [1] refluxing diphenylcarbodiimide with sodium azide in dry ethanol for 5 h obtained a cyclic product which was described by him as 1-phenyl-5-anilinotetrazole. This product had the same properties as a compound prepared by the reaction of aminodiphenylguanidine with $HNO_2$ [2]. The American authors [3] studying the alkylation of tetrazole ring have modified Stollé's procedure using azoimide in benzene. In this way, refluxing the reaction mixture for 90 min, they prepared a series of 1-alkyl-5-alkylaminotetrazoles in high yields.

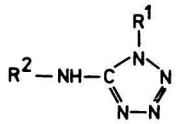
The present work reports on the preparative use of reaction of symmetrical diarylcarbodiimides and dicyclohexylcarbodiimide with azoimide. Likewise *Percival* and *Herbst* [3], we have employed $HN_3$ in benzene solution and the reaction was performed at room temperature, because of an increased reactivity of these derivatives. 1-Cyclohexyl-5-cyclohexylamino- and 1-aryl-5-arylaminotetrazoles *I—VIII* (Table 1) have been obtained in this reaction.

As alicyclic, also the majority of aromatic carbodiimides afford with azoimide at room temperature 1,5-disubstituted tetrazoles, prevailingly during short reaction times and in very good yields (Table 1). Evidently, it is possible to perform the reaction at moderate conditions enabling a safe experimental course.

The structure of reaction products has been determined on the basis of spectral measurements. Tetrazoles show the characteristic absorption bands (IR) at 1640—1335 and 1200—900 $cm^{-1}$ [4]. Because of the complete interaction of C=C, C=N, and N=N vibrations in a heterocycle, the unambiguous assignment of vibrations to the individual bonds could not be made. The absorption bands at

*Table 1*

Properties and analyses of the synthesized derivatives



| Compound | $R^1 = R^2$ | Formula | $M$ | Calculated/found % C | % H | % N | Yield % | M.p. °C | Reaction time, h |
|---|---|---|---|---|---|---|---|---|---|
| *I* | Cyclohexyl | $C_{13}H_{23}N_5$ | 249.36 | 62.61 | 9.29 | 28.08 | 97 | 204—204.5 | 0.25 |
| | | | | 62.97 | 9.31 | 28.27 | | | |
| *II* | 4-$CH_3O$—$C_6H_4$ | $C_{15}H_{15}N_5O_2$ | 297.31 | 60.59 | 5.08 | 23.55 | 100 | 153—154 | 1.75 |
| | | | | 60.54 | 5.07 | 23.45 | | | |
| *V* | 4-Br—$C_6H_4$ | $C_{13}H_9N_5Br_2$ | 395.06 | 39.52 | 2.29 | 17.72 | 41 | 194—195 | 2.26 |
| | | | | 39.71 | 2.27 | 17.59 | | | |
| *VI* | 2,4-$(CH_3)_2C_6H_3$ | $C_{17}H_{19}N_5$ | 293.37 | 69.59 | 6.52 | 23.87 | 81 | 133—135 | 10 |
| | | | | 69.60 | 6.65 | 23.88 | | | |
| *VII* | 3,4-$(Cl)_2$—$C_6H_3$ | $C_{13}H_7N_5Cl_4$ | 375.04 | 41.63 | 1.88 | 18.67 | 32 | 220—222 | 12 |
| | | | | 41.32 | 1.90 | 18.53 | | | |
| *VIII* | α-Naphthyl | $C_{21}H_{15}N_5$ | 337.38 | 74.76 | 4.48 | 20.75 | 77 | 183—185 | 12 |
| | | | | 74.65 | 4.52 | 20.76 | | | |

Physical data of compounds *III* ($R^1 = R^2 = 4\text{-}CH_3\text{—}C_6H_4$, yield 70%, reaction time 0,66 h) and *IV* ($R^1 = R^2 = C_6H_5$, yield 68%, reaction time 0.07 h) are in accord with the literature data [1].

1640—1335 $cm^{-1}$ are characteristic of stretching and at 1200—900 $cm^{-1}$ of skeletal vibrations of a cycle. The investigated 1,5-disubstituted tetrazoles give in these regions characteristic absorptions at 1040, 1090, 1120 $cm^{-1}$ and a strong doublet at 1580 and 1605 $cm^{-1}$ which was not observed in the spectrum of compound *I* (only a singlet at 1584 $cm^{-1}$), since the absorption at 1605 $cm^{-1}$ is due to the vibrations of aromatic ring (Table 2).

1-*H*-Tetrazole absorbs in the ultraviolet region of spectrum, below 205 nm [5]. Substitution at positions 1 and 5 causes an expected bathochromic shift. The prepared tetrazoles show (Table 3) two intensive absorption maxima, the former almost always at 205 nm and the latter being shifted towards the longer wavelengths.

As it is evident from Table 3, $^1$H-n.m.r. spectrum of *IV* is characterized by a resolved multiplet $R^2$ (the low field *ortho* protons $H_o$ are shifted by 0.42 p.p.m. towards the *meta* protons, and by 0.69 p.p.m. towards the *para* protons) and by a sharp singlet $R^1$ at 7.60 $\delta$. Thus the chemical shifts of all phenyl protons $R^1$ are congruent and exclude any deshielding effect on the *ortho* protons, like in the case of phenyl hydrogen atoms of some 1-alkyl-5-phenyltetrazoles [6]. This phenome-

*Table 2*

Infrared absorption bands ($cm^{-1}$)

| Compound | Tetrazole ring breathing vibrations | | | $\nu$(—N—N=N—) | Tetrazole ring stretching band | $\nu$(C=C)$_{arom}$ | | $\nu$(NH) |
|---|---|---|---|---|---|---|---|---|
| *I* | 1012 w | 1092 s | 1122 w | 1300 w | 1588 s | — | — | 3417 m |
| *II* | 1043 m | 1087 m | 1115 w | 1304 m | 1584 s | 1534 m | 1608 s | 3409 m |
| *III* | 1022 w | 1086 m | 1122 w | 1318 w | 1575 s | 1533 w | 1605 s | 3410 m |
| *IV* | 1042 w | 1091 m | 1119 w | 1322 w | 1578 s | 1504 m | 1605 s | 3410 m |
| *V* | 1015 m | 1073 m | 1115 w | 1315 w | 1571 s | 1498 m | 1605 s | 3410 m |
| *VI* | 1022 m | 1086 m | 1122 w | 1318 w | 1575 s | 1535 w | 1605 s | 3410 m |
| *VII*[a] | 1025 w | 1095 m | 1132 m | 1320 w | 1563 s | 1484 s | 1600 s | 3275 s |
| *VIII* | 1023 w | 1094 s | 1115 w | 1304 m | 1587 s[b] | 1535 w | | 3401 s |

*a*) Recorded for KBr tablets.
*b*) Broad band overlapped with the $\nu$(C=C) band.
s — strong, m — medium, w — weak.

non reveals that a benzene ring $R^1$ of compound *IV* is not coplanar with the tetrazole ring.

According to literature [7—9], deshielding prevailingly caused by anisotropy of a heterocyclic ring always decreases or disappears when in the position adjacent to the phenyl group a new substituent is introduced, sterically thus breaking the coplanarity of two aromatic systems. Further, from two signals of methyl groups present in *II* and *III*, the resonance of $CH_3$ from $R^1$ appears at lower field due to the electron withdrawing effect of tetrazole ring. This occurs also in the case of *o*- and *p*-methyl groups of *VI*.

Because of the complex multiplets of aromatic protons, the spectra of compounds *VI*, *VII*, and *VIII* were not analyzed. Besides the described absorptions, all investigated compounds show a broad singlet at 8.24—9.46 $\delta$ belonging to NH proton.

Papers on mass spectrometry of tetrazole and its derivatives are rather scarce [10, 11]. Detailed studies on methyl tetrazoles were accomplished by *Forkey* and *Carpenter* [12]. From the derivatives reported in this work, the behaviour of 1-phenyl-5-anilinotetrazole by an electron impact is described. Mass spectrum of this compound is shown in Fig. 1. As in the other tetrazoles, the main degradation reaction follows the expulsion of nitrogen molecule and formation of ion $[M^{+\bullet} - N_2]$ at *m/e* 209 which after the loss of hydrogen radical afforded a basic peak of spectrum.

Formation of the remaining specimens is elucidated by further cleavage of these key fragments (Scheme 1). The individual fragmentation transitions have been

*Table 3*

Ultraviolet and $^1$H-n.m.r. data of the substituted tetrazoles

| Compound | $\lambda_{max}$, nm (log $\varepsilon$) | | $R^1$ | | $R^2$ | |
|---|---|---|---|---|---|---|
| *I* | 204 (3.59) | 232 (3.63) | 1.62 (m, 10, $CH_2$) | 4.21 (m, 1, CH) | 1.62 (m, 10, $CH_2$) | 3.51 (m, 1, CH) |
| *II* | 204 (4.46) | 243 (4.30) | 7.11 (d, $2H_{arom}$) | 7.51 (d, $2H_{arom}$) | 6.85 (d, $2H_{arom}$) | 7.57 (d, $2H_{arom}$) |
| | | | 3.91 (s, 3, $CH_3$) | | 3.76 (s, 3, $CH_3$) | |
| *III* | 205 (4.48) | 244 (4.18) | 7.46 (s, $4H_{arom}$) | | 7.10 (d, $2H_{arom}$) | 7.55 (d, $2H_{arom}$) |
| | | | 2.42 (s, 3, $CH_3$) | | 2.22 (s, 3, $CH_3$) | |
| *IV* | 205 (4.44) | 244 (4.14) | 7.60 (s, $5H_{arom}$) | | 7.00 (t, *p*-H) | 7.27 (t, *m*-H) |
| | | | | | 7.69 (d, *o*-H) | |
| *V* | 205 (4.53) | 250 (4.32) | 7.56 (d, $2H_{arom}$) | 7.76 (d, $2H_{arom}$) | 7.37 (d, $2H_{arom}$) | 7.60 (d, $2H_{arom}$) |
| *VI* | 207 (4.54) | 233 sh | 6.97—7.47 (m, $6H_{arom}$) | | 6.97—7.47 (m, $6H_{arom}$) | |
| | | | 2.12 (s, 3, *o*-$CH_3$) | 2.36 (s, 3, *p*-$CH_3$) | 2.09 (s, 3, *o*-$CH_3$) | 2.21 (s, 3, *p*-$CH_3$) |
| *VII* | 207 (4.77) | 251 (4.34) | 7.57—8.12 (m, $6H_{arom}$) | | 7.57—8.12 (m, $6H_{arom}$) | |
| *VIII* | 220 (5.09) | 284 (4.17) | 7.38—8.21 (m, $14H_{arom}$) | | 7.38—8.21 (m, $14H_{arom}$) | |

s — singlet, d — doublet, t — triplet, m — multiplet.

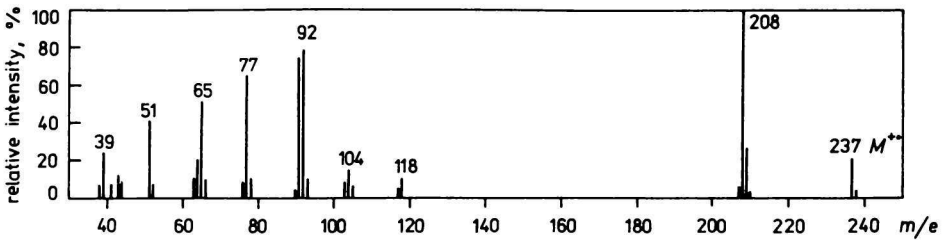
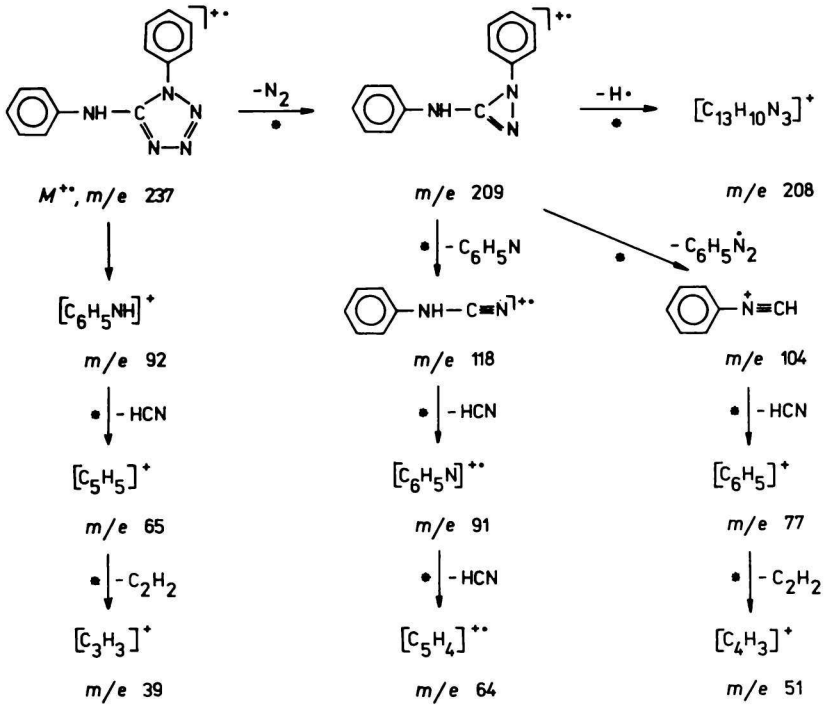



*Fig. 1.* Mass spectrum of 1-phenyl-5-anilinotetrazole.




*Scheme 1*
Fragmentation pattern of 1-phenyl-5-anilinotetrazole.

verified by the high voltage scan technique [13]. The spectra have to be measured with caution because there is a danger to obtain the thermally degraded products. Compound *IV* gives namely at 140°C an ion at *m/e* 194 having the relative intensity 72% and corresponding to the loss of $HN_3$ from $M^{+\bullet}$; at 80°C, however, the relative intensity of this ion is only 4%.

The Japanese authors [14] have obtained by the reaction of diphenylcarbodiimides with tosylazide in pyridine a mixture of products, of which the compound *IV* was shown to give the ions at *m/e* 237 ($M^{+\bullet}$), *m/e* 212, and *m/e* 209. Nevertheless, the existence of ion at *m/e* 212 is highly obscure because it corresponds to the loss of 25 mass units and, moreover, it was not present in our spectrum.

## Experimental

Dicyclohexylcarbodiimide is commercially available and the other carbodiimides have been prepared according to [15]. Azoimide in benzene solution was obtained by the reaction of sodium azide with sulfuric acid [16] and the concentration was determined by titration using NaOH solution on phenolphthalein.

Infrared spectra in the region of 700—3600 $cm^{-1}$ were measured on a UR-20 (Zeiss, Jena) instrument in NaCl cell (1.04 mm, concentration 0.025 M in chloroform). A polystyrene foil was used for calibrations. Data precision was $\pm 3$ $cm^{-1}$.

Ultraviolet spectra were recorded on a Specord UV VIS (Zeiss, Jena) instrument in the region of 200—800 nm; the concentration 3—$5.5 \times 10^{-5}$ M in methanol.

$^1$H-N.m.r. spectra were recorded on a Tesla BS 847 C (80 MHz) spectrometer using hexamethyldisiloxane as internal standard at 25°C. The chemical shifts (p.p.m.) were calculated on TMS. The samples were measured in acetone-$d_6$ except for *VII* and *VIII* which were measured in DMSO-$d_6$.

Mass spectra were run with an MS 902 S (AEI Manchester) spectrometer using direct inlet system at 70 eV, trap current 100 μA, and the temperature of ionization chamber was 80°C.

### *1,5-Disubstituted tetrazoles*

To a solution of freshly prepared carbodiimide (10 mmol) in benzene (10—20 ml), 20 ml of 1 M solution of azoimide (20 mmol) in benzene were added and the reaction mixture was allowed to stand for a period shown in Table 1. The product was separated on a Büchner funnel and combined with a portion obtained from mother liquor. The material was then recrystallized from ethanol. The properties and analytical data of synthesized tetrazoles are given in Table 1.

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