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Substituent Effects in the Rearrangement of 4-Alkyl-4*H*-1,2,4-triazoles

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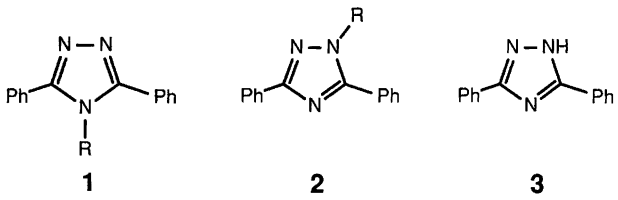
A study of the thermal rearrangement of neat 4-alkyl-substituted 4*H*-1,2,4-triazoles to the corresponding 1-alkyl-1*H*-1,2,4-triazoles showed that the rearrangement was accompanied by formation of 3,5-diphenyl-1*H*-1,2,4-triazole and alkenes. The composition of the product mixture depended on the nature of the 4-alkyl group. More branched alkyl groups caused more elimination. The data were best rationalized by assuming an initial nucleophilic bimolecular activation step where two triazole molecules formed a dialkyltriazolium triazolate salt. A subsequent reaction of this salt with a triazole nucleophile/base yielded the rearrangement and elimination products.

Thermal rearrangements of 4-alkyl substituted 4*H*-1,2,4-triazoles, **1**, to the corresponding 1-alkyl-1*H*-1,2,4-triazoles, **2**, have in a recent publication been shown by ^{15}N-labelling experiments not to involve any ring cleavage reactions, but to take place via an *N*4-alkyl cleavage mechanism.[1] Previous investigations have also revealed evidence for either an ion-pair mechanism or a bimolecular displacement mechanism, even though the possibility of concerted group shift reactions could not be totally ruled out.[2] A reinvestigation of the rearrangement reactions showed that varying amounts of 3,5-diphenyl-1*H*-1,2,4-triazole, **3**, was generated under the reaction conditions, Scheme 1. Compound **3** might be formed from **1** or **2** by elimination reactions. Mechanistically, the formation of **3** together with **2** may reflect the existence of a common intermediate, leading to both types of product. Thus, the ratio between **3** and the rearranged products **2** should depend on the nature of the 4-alkyl substituents. The reactions may proceed as a concerted shift reaction, through formation of charged intermediates, e.g., ion-pairs, or via a bimolecular-type rearrangement mechanism. Obviously complete product studies will facilitate the elucidation of the mechanism. To that end we studied the thermal behaviour of a series of 4-alkyl substituted 4*H*-1,2,4-triazoles, **1a–1h**, where the stereoelectronic nature of the 4-substituent was varied. The effect on product composition in such experiments should reflect the nature of the rearrangement reaction. However, we should keep in mind, that by changing substituents, we may actually influence the exact nature of the mechanism involved.



1 **2** **3**

Scheme 1.

Results and discussion

The results obtained by thermolysis of representative examples of 4-alkyl-4*H*-1,2,4-triazoles are compiled in Table 1. We chose a series of alkyl substituents for the triazoles. Examples including tertiary alkyl substituents were also desired. Unfortunately, it was not possible to

Table 1. Thermolysis of 4-alkyl-3,5-diphenyl-4*H*-1,2,4-triazoles, **1**.

		Reaction conditions		Product(s), yield (%)[a]			Ratio
Entry	R	*T*/°C	*t*/min	**1**	**2**	**3**	**2:3**
1a	Methyl	320	30		92		
1b	Ethyl	335	30		85	4	21.3
1c	1-Octyl	380	10		57	8	7.1
1d	2-Propyl	360	20	(12)	(53)	(21)	2.5
1e	2-Butyl	330	36		37	43	0.86
1f	2-Octyl	320	30		14	83	0.17
1g	Cyclohexyl	380	10		12	33	0.36
1h	Benzyl	320	33	43	33	7	4.7

[a] Yields are isolated yields after chromatographic work-up. Numbers in parentheses are GLC yields.

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obtain such triazoles. In an earlier synthetic study,[3] we observed that attempts to prepare triazoles substituted with tertiary alkyl groups in the 4-ring position, did not lead to the expected products. In those cases **3** was isolated as the sole product. The identities of the obtained products, **2a–2h**, were established by comparison of their chromatographic and spectroscopic properties with those of the authentic compounds. Authentic 1-alkyltriazoles were prepared by alkylation of **3** with the appropriate alkyl halides or tosylates, (NaH–DMF at room temperature). This method, however, failed in some cases, e.g., for the synthesis of 1-cyclohexyl-3,5-diphenyl-1*H*-1,2,4-triazole, **2g**, which, however, could be prepared in modest yield from cyclohexanol and **3** using the Mitsunobu reaction conditions.[2]

Rearrangement of triazoles, **1**. Thermolysis of the 4-methyl substituted triazole, **1a**, yielded the rearranged product **2a** as the exclusive product in 92% isolated yield. Compounds **1a** and **2a** did not equilibrate, which was established by a careful spectroscopic and chromatographic analysis of the reaction mixture after thermolysis of **2a**. The corresponding ethyl substituted triazole **1b**, however, gave the rearranged product **2b** (85%) together with a 4% isolated yield of **3**. Thermolysis of the 4-(1-octyl) substituted triazole **1c** similarly rearranged to product **2c** as the major product (57%) with 8% of **3** as the by-product. Increasing the size as well as the branching of the alkyl group, resulted in reduced amounts of rearrangement products together with increasing amounts of elimination products. Thus, triazoles substituted in the 4-ring position with secondary alkyl groups, i.e., 2-propyl, 2-butyl or 2-octyl, **1d–1f**, yielded increasing amounts of the elimination product **3**. In the series **1b–1f**, the ratio **2**:**3** decreased from 21 to 0.17. The cyclohexyl compound, **1g**, gave less elimination than expected. This can be ascribed to the special steric conditions of cyclohexanes. Thermolysis of the 4-benzyltriazole, **1h**, gave 33% **2h** together with 43% unchanged **1h** and 7% elimination product. From these results we have now established that the structure of the 4-alkyl group indeed affected the relative rates of rearrangement and elimination.

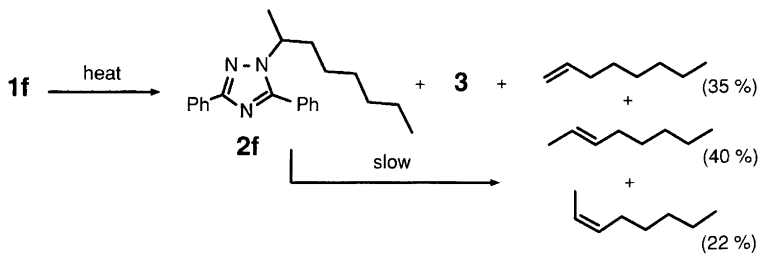
Elimination. Analysis by GC–FTIR and GC–MS of the reaction mixture from the thermolysis of **1c** revealed the presence of 1-octene. No other octene isomers could be detected. Using the same experimental techniques, the 2-octyltriazole, **1f**, was shown to yield a mixture of 1-octene (35%), (*E*)-2-octene (40%) and (*Z*)-2-octene (22%) together with an unidentified octene (3%) which, based on the IR data, may be one of the 3-octene isomers. Reaction of **1g** yielded **2g** together with **3** and cyclohexene, which was identified in the reaction by the GC–FTIR technique. The benzyl-substituted triazole, **1h**, gave the expected product, **2h**, and, surprisingly, also **3**. The identity of the benzyl elimination product has so far not been established.

Formation of elimination products may reflect an intrinsic property of the rearrangement reaction. However, they may also be due to a subsequent elimination of the rearranged product **2**. To test this possibility we thermolysed the 1-alkyltriazoles. Thus, while thermolysis of **2e** at 336°C for 30 min gave only 3% of **3**, thermolysis of **1e** at 330°C for 36 min yielded 43% of **3**. It therefore became clear that the bulk of the elimination products were formed by a reaction of the starting material or by a reaction associated with an intermediate in the rearrangement reaction.

Mono- or bi-molecular rearrangement? Possible mechanisms for the rearrangement may involve mono- or bimolecular-type reactions, eventually with ion-pair intermediates.[2] A possible supplement or alternative to this mechanism has been proposed by Bentley *et al.* which involved an initial formation of salts (triazolium/triazolate) intermediates.[4] Thermolysis of 4- to 1-alkyl-3,5-diphenyl-1*H*-1,2,4-triazoles was proposed to be thermodynamically controlled, involving two transition states. The first step is a bimolecular dealkylation of one molecule by another, leading to a salt or ion pair as an intermediate.[4]

If the rearrangement takes place by an ionic mechanism, we assume that the formation of a salt (**5**, **6**) or ion-pair intermediates (**4**), will be rate determining and product formation therefore sensitive to structural changes of the 4-alkyl group. The existence of ion-pair mechanisms cannot be ruled out and would open up the possibility for unimolecular rearrangements, which would be difficult to distinguish mechanistically from concerted sigmatropic shift reactions.

We then addressed the problem of uni- or bi-molecular reactivity. According to earlier results from an investigation of optically active triazoles, the rearrangement agreed best with a bimolecular mechanism, e.g., involving



Scheme 2.

nucleophilic attack of the *N*1-triazole atom of one molecule at the triazole-bearing carbon of the 4-alkyl group of another triazole molecule. Thus, thermolysis of 4-[(*S*)-2-butyl]-3,5-diphenyl-4*H*-1,2,4-triazole, (*S*)-(+)-**1e**, proceeded with inversion of configuration around the chiral carbon atom to yield 1-[(*R*)-2-butyl]-3,5-diphenyl-1*H*-1,2,4-triazole, (*R*)-(−)-**2e**.[2] However, 25–30% racemization was detected. A clean nucleophilic mechanism would not explain how the observed partial racemization takes place. The proposed mechanism sketched above is therefore either wrong, or is subject to competing reactions. Unimolecular formation, e.g., via ion pair **4** could, for example, explain the partial racemization.

To test for the possible formation of **5** we performed partial thermolysis of (*S*)-(+)-**1e** (reaction conditions 324–336 °C, 10 min). The components of the reaction mixture were isolated by preparative TLC and proved to comprise 63% of pure starting material, **1e**, 14.5% of **3**, together with 8.6% of rearranged 1-(2-butyl)-3,5-diphenyl-1*H*-1,2,4-triazole, **2**. Circular dichroism, CD, spectra of the recovered (*S*)-(+)-**1** were indistinguishable from the CD spectrum of an authentic sample.

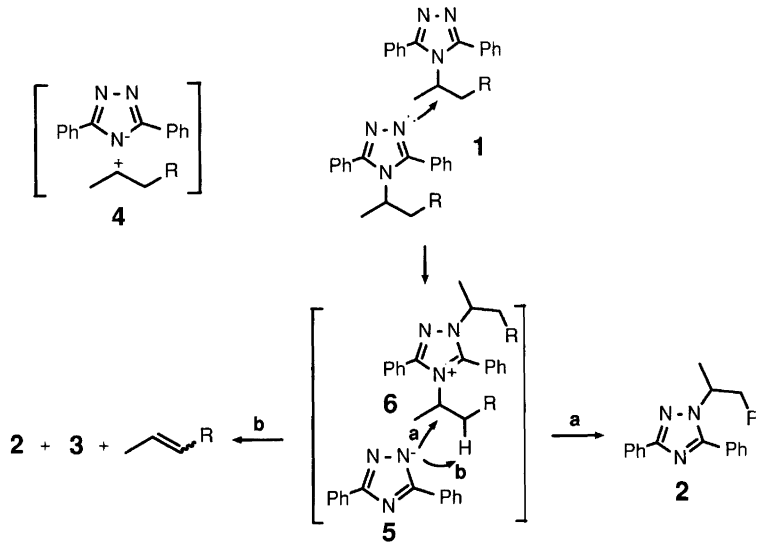
Another reason for the racemization, namely, thermal instability of the rearranged product was then considered. However, thermolysis of pure 1-[(*S*)-2-butyl]-3,5-diphenyl-1*H*-1,2,4-triazole, (*S*)-(+)-**2e**, at 330–336 °C for 30 min, and subsequent preparative TLC purification, yielded 25% of **2e** together with 3% of eliminated **3a**. The CD spectrum of **2e** was identical in all details with that of authentic (*S*)-(+)-**2e**. We therefore concluded, that racemization of the starting material, **1e**, did not take place prior to rearrangement, and also that racemization was not caused by thermal instability of the rearranged product.

Based on these results, ion pairs like **4** most likely do not participate in the reaction, thereby excluding an ionic unimolecular rearrangement mechanism. The observations also disfavour a concerted rearrangement reaction. Altogether, the experimental evidence agrees best with the type of bimolecular mechanism sketched in Scheme 3. The partial racemization has so far not been explained, but must involve reactive intermediates formed in the course of the rearrangement reaction. Although the experimental material can give no definite proof, we now propose that the racemization takes place owing to an attack of *N*1 of **1e** at the chiral alkyl carbon of **2e**, causing a double inversion, i.e., retention of the configuration of the alkyl group.

The observed substituent effect on the distribution of rearranged vs. eliminated products appeared to parallel the structural effects observed for substrates in the classical competition between nucleophilic substitution and elimination. Substitution and β-elimination are closely related. If the substrate has one or more hydrogens bonded to a β-carbon attached to the carbon bearing the leaving group, the hydrogen can be lost as a proton, generating the olefinic bond. Increasing branching and size of the alkyl group generally retards S_N2-type reactions and E2 reactivity increases with α- and β-substitution.[5] Thus, S_N2 reaction rates should decrease in the order methyl > ethyl > 2-butyl. The S_N1-type reaction will increase in the same order. We have shown before that, here, we need only consider the bimolecular reactions (S_N2/E2). Thus, our observations regarding formation of rearranged vs. elimination may be rationalized in terms of transformations proceeding via competing substitution and elimination pathways.

The series of substituted triazoles studied here exhibit the behaviour of competing rearrangement and elimination reactions. Assuming the rearrangement and elimination reactions proceed via a common intermediate in competing reactions, we would expect to observe increasing amounts of elimination products as the alkyl substituents are increased in size and degree of branching. This was in agreement with our observations. Actually, the thermolysis reactions of the triazoles behaved very much like the solvolysis of alkyl halides.[6] Consider, e.g., example **1f**: the elimination gave a large amount of the Hofmann product (1-octene, 35%). For E1 eliminations the Saytzev products predominate over the Hofmann elimination products, and the composition of the olefin mixture will be independent of the leaving group, being dependent only on the stability of the products. The (*E*)-alkenes are more stable, and will be the major products. In our experiments (*Z*)- and (*E*)-octenes were formed in comparable amounts (22 and 40%, respectively). The large proportion of the *Z* isomer in the octene mixture gave a clear indication of the absence of a first-order elimination mechanism. Most E2 reactions also yield the Saytzev products, but here the composition is also dependent on the stereoelectronic properties of the leaving group as well as the stereochemistry of the alkyl group and the strength of the base. Large and bulky groups cause steric interactions to determine the course of the E2 process, often favouring the Hofmann products. The orientation of the double bond in the octene products resembles the composition in the E2 reaction of 2-bromopentane with ethoxide in methanol.[7] We therefore propose an elimination mechanism for the triazoles, closely resembling an E2 reaction. In conclusion, rearrangement and elimination both were bimolecular reactions, with no signs of unimolecular mechanisms or even borderline cases.

Our experimental results agreed well with a mechanism proceeding through formation of salt (triazolium, **6**/triazolate, **5**) as earlier proposed by Bentley *et al.* for the rearrangement of other triazoles.[4] The salt is formed by an initial substitution reaction involving two triazole molecules, one functioning as a nucleophile (*N*1) and the other as the substrate for a nucleophilic displacement reaction, where the triazole is the leaving group, Scheme 3. Ion pairs do not appear to play a role, but cannot be ruled out for compounds from which a stabilized carbocation can be formed, e.g., the 4-*tert*-alkyl substituted triazoles. The salt formation will probably be rate determining. In the next step, the triazolate anion, **5**, or a



Scheme 3.

neutral 4-alkyltriazole, **1**, will react with the dialkyltriazolium species, **6**, at what appears to be the more reactive site at the 4-alkyl group. This can take place either as a substitution reaction at the α-carbon, resulting in the formation of the 1-alkyltriazole, **2**, (path **a**) or by abstraction of a β-hydrogen in an elimination reaction (path **b**) giving **3** and an olefin. The regio- and stereo-isomerism of the olefin will be determined by the preferred conformations around the C–C bonds or by thermal equilibration at the elevated temperatures. The basicity of the active base will be virtually the same in all examples if the reactions involve **1**, and the same if **5** is the active base. The ratio between isolated **2** and **3**, respectively, is determined by the relative energies of activation for paths **a** and **b**. However, basicity and nucleophilicity of the neutral triazoles **1** are too weak, even at elevated temperatures, for them to cause the respective elimination and substitution reactions. We therefore consider it more likely that the triazolate anion **5**, in all cases, promotes these reactions.

Conclusions. The rearrangement of the series of 4-alkyltriazoles indicated that unimolecular reactivity or formation of ion pairs did not take place for the compounds studied. The observations were in agreement with an initial nucleophilic bimolecular activation step in which two triazoles form a dialkyltriazolium triazolate salt and a subsequent reaction of the dialkyltriazolium ion with either the anion or a neutral triazole to form the 1-alkyltriazole product molecule. The results do not fully elucidate all the details of the rearrangement mechanism.

Experimental

General. ^{1}H and ^{13}C NMR spectra were recorded on a JEOL FX-100 NMR spectrometer, or on a JEOL JNM-EX400 FT NMR SYSTEM, using $CDCl_3$ as the solvent and tetramethylsilane (TMS) as the internal standard. IR and GC–IR spectra were obtained on a Nicolet 20-SXC FT-IR (GC Carlo Erba 5160, 25 m, CP-Sil-5 CB). Mass spectra were recorded on an AEI MS-902 spectrometer at 70 eV (IP) and 200°C inlet temperature. GC–MS spectra were obtained on a Hewlett Packard 5985A GC–MS system. CD spectra were recorded at room temperature on a Jobin Yvon Auto Dictograf Mark IV. GC measurements were performed on a Varian 3700 gas chromatograph equipped with a BP-1 capillary column (24 m). Preparative TLC was performed on 20 × 20 cm glass plates covered with 1 mm Merck silica gel $HF_{254+366}$. All melting points are uncorrected.

4-Alkyl-4H-1,2,4-triazoles, **1** were all prepared by reacting bis(α-chlorobenzylidene)hydrazine with the appropriate amines according to the procedure described in the literature.[3] In the following only compounds not previously described are reported.

4-Benzyl-3,5-diphenyl-4H-1,2,4-triazole, **1h**.[8] M.p. 216–218°C (crystallized from EtOH, lit.[8] 218–220°C). The IR spectrum was identical with spectra described in the literature.[9] ^{1}H NMR (100 MHz): δ 5.28 (s, 2 H), 6.75–6.94 (m, 2 H), 7.17–7.32 (m), 7.32–7.51 (m) and 7.51–7.68 (m, 13 H). ^{13}C NMR (25 MHz): δ 48.7, 126.1, 127.1, 128.3, 129.1, 129.3, 130.5, 136.1, 155.8. MS [*m/z* (% rel. int.)]: 312 (8), 311 (36, M^+), 310 (13), 92 (7), 91 (100), 89 (29), 77 (6), 65 (9), 63 (11).

Thermolysis of 4-alkyl-3,5-diphenyl-4H-1,2,4-triazoles, **1**. *General procedure.* Samples of neat triazoles (30–70 mg, ca. 0.15 mmol) were placed under vacuum in sealed glass tubes (inner diameter 5 mm, length 40 mm) and placed in an oven at temperatures in the range 320–380°C. The reaction conditions for the thermolysis are shown in

Table 1. The reaction mixtures were then subjected to preparative TLC, which yielded the pure products. The products were identified by comparison of their spectroscopic properties with those of authentic samples, or by their characteristic spectroscopic properties.

*Partial thermolysis of neat 4-[(S)-2-butyl]-3,5-diphenyl-4H-1,2,4-triazole, (S)-(+)-***1e**. Thirty mg (0.12 mmol) of (*S*)-(+)-**1** were placed in a sealed glass tube and heated in an oven at 324–336°C for 10 min. The reaction mixture was then subjected to preparative TLC. Two fractions were isolated. *Fraction 1* (R_f = 0–0.04) was solved in dichloromethane (15 ml), extracted with 2 M NaOH (2 × 5 ml), water (5 ml) and then dried over anhydrous $MgSO_4$. The solvent was evaporated under reduced pressure and the crude product dried under vacuum, yielding 11.7 mg, (63%) of pure (*S*)-(+)-**1**, (99% by GC). The CD spectrum of the product was identical with that of authentic (*S*)-(+)-**1e** indicating that no racemization had occurred. The basic extract was acidified with HCl and extracted with dichloromethane (15 ml). The organic phase was washed with water (5 ml), dried over anhydrous $MgSO_4$ and the solvent evaporated under reduced pressure. The yield of **3** was 2.4 mg (14.5%). *Fraction 2* (R_f = 0.18–0.24) was isolated and found to contain almost pure 1-(2-butyl)-3,5-diphenyl-1*H*-1,2,4-triazole, **2e**, (94% by GC), yield 1.6 mg (8.6%).

*Thermolysis of neat 1-[(S)-2-butyl]-3,5-diphenyl-1H-1,2,4-triazole, (S)-(+)-***2**. (*S*)-(+)-**2e**, (30.1 mg, 0.109 mmol) was placed in a sealed glass tube and heated in an oven at 330–336°C for 30 min. Two fractions were isolated by preparative TLC using $CHCl_3$ as the eluent. *Fraction 1* (R_f = 0.48–0.65) contained 7.5 mg (25%) of the starting compound. The CD spectra were identical in all details with that of authentic (*S*)-(+)-**2**, indicating that no racemization had taken place during the reaction. *Fraction 2* (R_f = 0–0.15) contained 0.8 mg (3%) of **3**. The ^{1}H NMR, IR and MS spectra were in agreement with those of authentic samples.

Synthesis of 1-alkyl-3,5-diphenyl-1H-1,2,4-triazoles, **2**. The 1-alkyltriazoles were prepared from 3,5-diphenyl-1*H*-1,2,4-triazole, **3**, by a modification of the alkylation procedure described by Atkinson and Polya.[5] Thus, **3** (0.47–4.52 mmol), NaH (2–3 equiv.) in DMSO (or DMF) (**3** in 5–10 weight %) were stirred for 1–2 h at room temperature under a nitrogen atmosphere. Alkyl halide (or alkyl tosylate) (1.0–1.5 equiv.) was then added, and the reaction mixture stirred overnight. The progress of the reaction was monitored by GC. The excess of NaH was then decomposed by addition of water and the reaction mixture was dissolved in dichloromethane after which it was washed consecutively with 1 M HCl, 2 M NaOH and water and then dried ($MgSO_4$). The solvent was evaporated off under reduced pressure. Isolated yields and spectroscopic data are reported in the following for the individual triazoles.

1-(1-Octyl)-3,5-diphenyl-1H-1,2,4-triazole, **2c**. The yield was 1.16 g (77%), as an oil of 95% purity according to GC. ^{1}H NMR (100 MHz): δ 0.86 (t, 3 H, J = 5.9 Hz), 1.22 (br s, 10 H), 1.74–2.10 (m, 2 H), 4.21 (t, 2 H, J = 7.5 Hz), 7.35–7.59 (m, 6 H), 7.59–7.73 (m, 2 H), 8.10–8.25 (m, 2 H). ^{13}C NMR (25 MHz): δ 14.1, 22.6, 26.5, 29.0, 30.1, 31.7, 49.3, 126.4, 127.2, 128.5, 128.9, 129.6, 130.0, 131.2, 155.5, 161.2. IR (neat): 3069, 2959, 2926, 2869, 2855, 1518, 1477, 1465, 1443, 1410, 1377, 1354, 1302, 1285, 1070, 1028, 1016, 789, 731, 695 cm^{-1}. MS [*m*/*z* (% rel. int.)]: 334 (22), 333 (80, M^+), 332 (18), 290 (29), 276 (31), 248 (12), 235 (49), 234 (93), 233 (13), 232 (20), 222 (44), 221 (98), 208 (22), 131 (16), 118 (31), 106 (10), 105 (100), 104 (87), 103 (14), 89 (24), 77 (40). Found: M^+ 333.2205. Calc. for $C_{22}H_{27}N_3$ M 333.2206.

*3,5-Diphenyl-1-(2-propyl)-1H-1,2,4-triazole (***2d**). The yield was 102 mg (87%), as an oil of 84% purity according to GC. ^{1}H NMR (100 MHz): δ 0.92 (t, 3 H, J = 7.3 Hz), 1.97 (sextet, 2 H, J = 7.3 Hz), 4.19 (t, 2 H, J = 7.3 Hz), 7.31–7.60 (m, 6 H), 7.60–7.75 (m, 2 H), 8.10–8.24 (m, 2 H). ^{13}C NMR (25 MHz): δ 11.0, 23.5, 50.8, 126.3, 129.9, 128.5, 128.9, 129.0, 130.0, 131.1, 155.6, 161.3. IR (neat): 3067, 2966, 2935, 2876, 1477, 1464, 1443, 1409, 1385, 1355, 1291, 1249, 1132, 1071, 1017, 789, 772, 732, 696 cm^{-1}. MS [*m*/*z* (% rel. int.)]: 264 (11), 263 (58, M^+), 234 (32), 221 (28), 131 (32), 118 (18), 105 (100), 104 (76), 103 (17), 89 (33), 77 (60). Found: M^+ 263.1418. Calc. for $C_{17}H_{17}N_3$ M 263.1423.

1-(2-Octyl)-3,5-diphenyl-1H-1,2,4-triazole, **2f**. The crude product was purified by preparative TLC using chloroform as the eluent. A fraction with $R_f(CHCl_3)$ = 0.21–0.50, yielded 170 mg (45%) of **2f** as an oil of 99.6% purity according to GC. ^{1}H NMR (100 MHz): δ 0.80 (t, 3 H, J = 7 Hz), 0.93–1.32 (m, 8 H), 1.56 (d, 3 H, J = 6.4 Hz), 1.64–2.30 (m, 2 H), 4.28–4.61 (m, 1 H), 7.30–7.68 (m, 8 H), 8.10–8.28 (m, 2 H). ^{13}C NMR (25 MHz): δ 14.0, 21.4, 22.5, 26.0, 28.7, 31.5, 36.6, 54.9, 126.4, 127.7, 128.4, 128.8, 129.0, 129.9, 131.4, 155.5, 161.2. IR (neat): 3068, 2955, 2930, 2857, 1518, 1478, 1457, 1443, 1405, 1373, 1343, 1302, 1175, 1132, 1071, 1028, 1016, 921, 788, 772, 732, 696, 676, 642 cm^{-1}. MS [*m*/*z* (% rel. int.)]: 334 (9), 333 (41, M^+), 332 (13), 249 (23), 248 (52), 234 (44), 222 (41), 221 (100), 208 (12), 199 (15), 173 (23), 172 (13), 155 (82), 118 (46), 112 (77), 105 (27), 104 (59), 103 (15), 92 (10), 91 (62), 89 (27), 84 (19), 83 (31), 77 (21), 71 (12), 70 (64), 69 (30). Found: M^+ 333.2206. Calc. for $C_{22}H_{27}N_3$ M 333.2205.

1-Benzyl-3,5-diphenyl-1H-1,2,4-triazole, **2h**. The crude product was purified by preparative TLC using chloroform as the eluent. From a fraction with R_f 0.7 were isolated 210 mg (75%) of the pure product. ^{1}H and ^{13}C NMR data were in agreement with those reported by Lopez *et al.*[10] IR (KBr): 3061, 3033, 2963, 2930, 1477, 1466,

1451, 1446, 1431, 1354, 1069, 1018, 790, 773, 734, 696 cm^{-1}. MS [*m/z* (% rel. int.)]: 312 (17), 311 (72, M^+), 310 (24), 104 (10), 92 (9), 91 (100), 89 (23), 77 (10).

*1-Cyclohexyl-3,5-diphenyl-1*H-*1,2,4-triazole*, **2g**. This compound was prepared by a modification of the Mitsunobu alkylation procedure from cyclohexanol and **3**, according to a procedure described earlier.[2] The crude product was purified by preparative TLC using chloroform as the eluent and eluting three times. From a fraction with R_f 0.27–0.42, were obtained 63.7 mg (23%) of **2g** as an oil of 99% purity according to GC. Crystallization from 95% EtOH gave the product with m.p. 82.5–87°C (lit.[11] m.p. 106–107°C). ^{1}H NMR (100 MHz): δ 1.10–1.60 (m, 3 H), 1.60–2.40 (m, 7 H), 4.22 (app. septet, 1 H), 7.28–7.70 (m, 8 H), 8.04–8.24 (m, 2 H). ^{13}C NMR (25 MHz, $CDCl_3$ int. ref. 77.0 ppm): δ 25.0, 25.4, 33.1, 58.0, 126.3, 128.4, 128.9, 129.9, 131.4, 154.6, 161.0. IR (neat): 3068, 3032, 2933, 2856, 1733, 1519, 1477, 1442, 1405, 1381, 1347, 1265, 1175, 1131, 1070, 1028, 1019, 997, 894, 822, 789, 776, 733, 695, 676 cm^{-1}. MS [*m/z* (% rel. int.)]: 304 (12), 303 (52, M^+), 302 (7), 222 (26), 221 (100), 118 (41), 104 (20), 89 (20), 83 (10), 77 (12), 69 (11). Found: M^+ 303.1729. Calc. for $C_{20}H_{21}N_3$ *M* 303.1736.

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