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Reaction of arylhydrazines with an α-alkynyl-carbonylic compound: an unexpected hydration reaction

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Abstract

The acid catalyzed reactions of three arylhydrazines with 4-phenyl-3-butynone in order to obtain the corresponding arylhydrazone were realized. The arylhydrazone reaction and an unexpected alkyne hydration reaction product were obtained when diphenylhydrazine was used. This product was identified by spectroscopic methods and X-ray diffractogram. A reaction mechanism is proposed for its formation.

Keywords: Arylhydrazines; α-Alkynyl-carbonylic compound; Hydration reaction

1. Introduction

Primary and secondary arylhydrazines react with carbonylic compounds (i.e., aldehydes and ketones) by standard procedures to yield arylhydrazones. Recently, it has been reported the synthesis of hydrazones in aqueous medium using microwaves.[1] *N*-Arylhydrazones are usually solids and their melting points can be used to identify the parent carbonyl compounds. Mono- and diarylhydrazones are also used in organic syntheses to form several heterocyclic compound derivatives, such as pyrrolidione and indole,[2] 1,2,4-triazolo[4,3-*a*]pyrimidine,[3] thiazolone, and oxathiolone.[4] For more than a century, it has been known that hydrazines readily react with acetylenic ketones to directly afford pyrazoles.[5] Moreover, α,β-unsaturated hydrazone compounds have been used as ligands to form either complexes with several metal compounds or dinuclear compounds.[6]

We herein present the results obtained for the reaction of 4-phenyl-3-butynone with hydrazine derivatives, in order to synthesize the corresponding hydrazone compound, where we found that the reaction with *N*,*N*-diphenylamine results in an unexpected alkyne hydration reaction in the corresponding hydrazone.

2. Results and discussion

The reaction time, yield, and some physical characteristics for the obtained products are listed in Table 1, and the overall reaction is outlined in Scheme 1.

Table 1
Results obtained for the reaction of **1.0** with arylhydrazines

Entry	Reaction time (h)	Color/mp (°C)	Yield (%)
1.1	2	Yellow liquid/—	24.4
1.2	3	Orange solid/173	75.7
1.3	4	Yellow crystals/116	70.2

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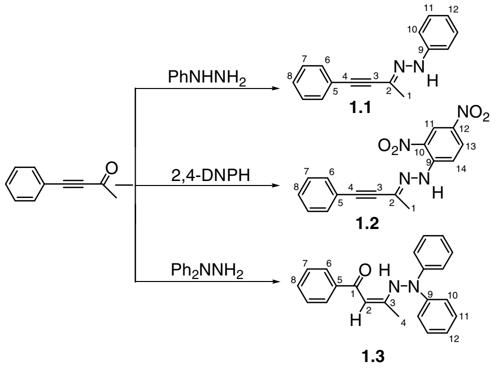


Scheme 1. Reaction of **1.0** with arylhydrazines.

As we had expected, the two arylhydrazones **1.1** and **1.2**, were obtained by a classically reported methodology, although the synthesis of entry **1.1** was previously reported by Maas et al., by means of the reaction of a 2-propyne iminium triflate with phenylhydrazine.[7] These compounds were identified by their spectroscopic data, mainly from those that reveal both the alkyne and imine functions, and from the corresponding molecular ion by EIMS.

Under the same conditions, the reaction between **1.0** and diphenylhydrazine resulted in the unexpected product **1.3**, and the spectroscopic data were in agreement with both a condensation reaction, to form the hydrazone fragment in equilibrium with the enamine tautomer, and a hydration reaction of the alkyne function, to form the more stable keto tautomer, and thus, the *Z* geometric alkene.

The following selected spectroscopic data confirm the formation of **1.3**: in the FTIR spectrum, a strong band at 1596 cm^{-1} is observed due to the carbonyl group, and the band corresponding to the alkyne function observed for **1.1** and **1.2** near to 2200 cm^{-1} is absent for product **1.3**; in the ^{1}H NMR technique, the signal at 5.80 ppm is assigned to the conjugated vinylic proton; in the ^{13}C NMR spectrum, a signal at 189.2 ppm assigned to the carbonyl carbon is observed; and finally, in the EIMS spectrum, the molecular ion at *m*/*z* 328 corresponds to the molecular formula $C_{22}H_{20}N_2O$ and a molecular weight of 328 g/mol.

An appropriate single crystal of this compound was obtained, and then used to collect X-ray intensity data on a Siemens P4/PC diffractometer. An ORTEP-like diagram,[8] Figure 1,[9] shows the molecular geometry, the thermal ellipsoids (35%), and the numbering scheme. Selected bond distances and angles are listed in Table 2.

Thus, if it is assumed that the first reaction step in forming this compound is the generation of the corresponding arylhydrazone, as is shown in the reaction mechanism proposed, Scheme 2, the next reaction step is presumably the formation of a vinyl-benzylic carbocation that reacts with water to produce the hydration reaction product of the alkyne function. This last step must necessarily proceed from the more stable vinyl-benzylic intermediate shown.

If it is considered that the hydration reaction could take place for both the phenylhydrazine and 2,4-dinitrophenylhydrazine reactions, then a vinyl-benzylic carbocation equivalent to that formed for the generation of **1.3**, would have to form for each of those reactions. Therefore, we realized a molecular dynamics computational study,[10] in order to calculate the activation energy for the vinyl-benzylic carbocation formation, for the three presented reactions. The calculated values are given in Table 3. These computational results reveal that the intermediate for the

Table 2
Selected bond lengths and angles for **1.3**

Bond distances		Angles	
Atoms	Å	Atoms	Degrees
O_1–C_1	1.252	C_3–N_1–N_2	122.1
N_1–C_3	1.346	O_1–C_1–C_2	121.6
C_1–C_2	1.420	O_1–C_1–C_5	118.4
C_2–C_3	1.368	C_2–C_1–C_5	119.9
C_3–C_4	1.495	C_2–C_3–C_4	122.2
N_1–N_2	1.396	C_1–C_2–C_3	124.9

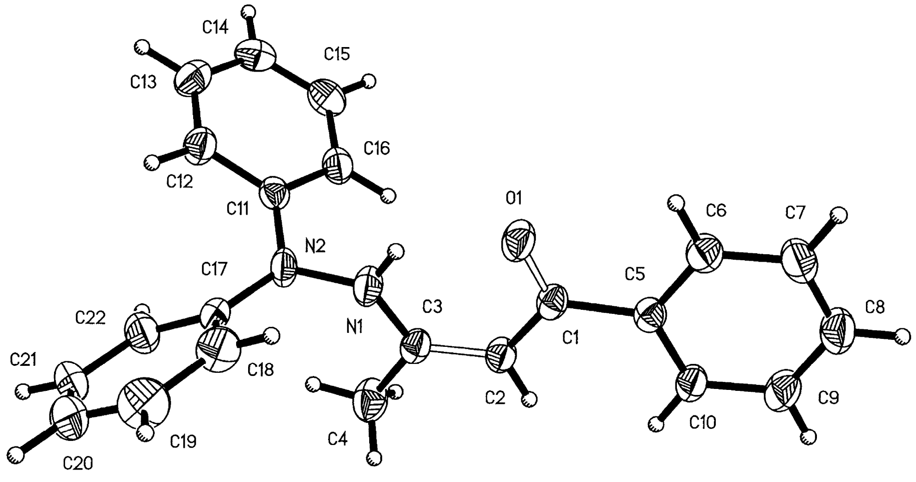
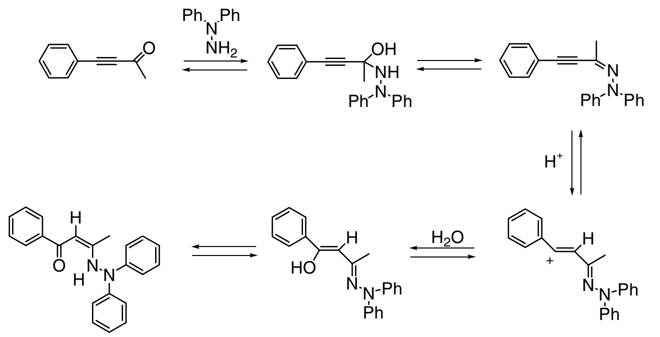


Fig. 1. ORTEP of **1.3**.



Scheme 2. Reaction mechanism proposed for the formation of 1.3.

Table 3
Calculated E_{act} values for the formation of vinyl-benzylic carbocations

Entry	E_{act} (kcal/mol)
1.1	13.4076
1.2	13.3668
1.3	11.8687

reaction of **1.3** is more easily formed, and is, in fact, the only one formed under the reaction conditions used.

3. Conclusion

The reaction of alkynone **1.0** with either phenylhydrazine or 2,4-dinitrophenylhydrazine produces the expected arylhydrazone. However, with diphenylhydrazine, under the same reaction conditions, an additional hydration reaction on the alkyne function is observed.

4. Experimental

4.1. General

FTIR spectra were recorded on a Perkin–Elmer 283 spectrophotometer using a dissolution technique. $CHCl_3$, ^1H, ^{13}C, DEPT, and HETCOR NMR spectra were obtained on either a VARIAN ST 200 MHz or Jeol Eclipse 300 MHz instrument, using $CDCl_3$ as solvent and TMS as internal reference. The EIMS spectra were obtained using a Hewlett Packard 5953 spectrometer. A suitable crystal was examined on a Siemens P4/PC diffractometer, and the structure was solved by direct methods using program SHELXS86, and refined by full matrix least-squares with SHELXL.[11] The position of the hydrogen atom on nitrogen atom was obtained from a difference Fourier map, and those hydrogen atoms attached to carbon atoms were assigned on idealized positions and forced to ride on parent atoms.

Prior to use, the employed solvents (THF and ethylic ether) were dried by treating them with metallic sodium and benzophenone as indicator. They were subsequently distilled under an argon atmosphere. Some reactions required an inert atmosphere (nitrogen), and the reagents were used as purchased. Column chromatography was performed on silica gel (70–230 mesh) and alumina.

4.2. Reaction of 4-phenyl-3-butynone with arylhydrazines (**1.1–1.3**)

4.2.1. General procedure

To a solution of 4-phenyl-3-butynone **1.0**, **CAUTION**: tear-producing liquid (3.5 mmol) in ethanol (100 mL), the corresponding hydrazine (3.5 mmol) and acetic acid (three drops) were slowly added. This mixture was magnetically stirred and placed under reflux until the alkynyl-ketone could no longer be detected by thin layer chromatography. After the lapse of the reaction time (Table 1), the solvent was distilled under vacuum, and the remaining mixture purified by column chromatography over alumina, using several gradients of hexane/ethyl acetate mixture. The corresponding reaction product was obtained as either a liquid or solid compound, as shown in Table 1.

4.2.2. 4-Phenyl-3-butynone phenylhydrazone (**1.1**)

FTIR ($CHCl_3$, cm^{-1}): 3311, 3055, 3025, 2919, 2202, 1601. ^1H NMR ($CDCl_3$, δ): 2.23 (3H, s, H_1), 6.86–7.53 (10H, m, H_{arom}), 8.28 (1H, s, **NH**). ^{13}C NMR ($CDCl_3$, δ): 22.1 (C_1), 81.0 (C_3), 101.2 (C_4), 113.0–133.1 (C_{arom}), 141.1 (C_2). EIMS (70 eV, m/z(%)): 234 (100) $[M^{+\cdot}]$, 233 (61.3) $[M^{+\cdot}-H]$, 218 (6.9) $[M^{+\cdot}-CH_4]$, 129 (12.5) $[C_8H_5N_2^+]$, 91 (18.1) $[C_6H_5N^{+\cdot}]$, 77 (13.8) $[C_6H_5^+]$.

4.2.3. 4-Phenyl-3-butynone 2,4-dinitrophenylhydrazone (**1.2**)

FTIR ($CHCl_3$, cm^{-1}): 3313, 3272, 3104, 2217, 2186, 1617, 1595, 1514. ^1H NMR (300 MHz, $CDCl_3$, δ): 2.35 (3H, s, H_1), 7.42–9.13 (8H, m, H_{arom}), 11.98 (1H, s, N*H*). ^{13}C NMR (75 MHz, $CDCl_3$, δ): 22.6 (C_1), 80.4 (C_3), 104.3 (C_4), 116.9–138.2 (C_{arom}), 144.2 (C_2). EIMS (70 eV, m/z(%)): 324 (100) $[M^{+\cdot}]$, 232 (28.1) $[M^{+\cdot}-2NO_2]$, 127 (19.4) $[M^{+\cdot}-C_9H_5N]$, 77 (8.8) $[C_6H_5^+]$.

4.3. 3-(N′,N′-Diphenylhydrazino)-1-phenylbut-2Z-en-1-one (**1.3**)

FTIR ($CHCl_3$, cm^{-1}): 3066, 2927, 1596, 1581, 1492 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$, δ): 2.12 (s, H_4), 5.80 (s, H_2), 7.06–7.96 (15H, m, H_{arom}), 12.6 (s, N*H*); ^{13}C NMR (75 MHz, $CDCl_3$, δ): 18.8 (C_4), 92.6 (C_2), 119.5–146.3 (C_{arom}), 166.4 (C_3), 189.2 (C_1) EIMS (70 eV, m/z(%)): 328 (100) $[M^{+\cdot}]$, 169 (33.1) $[C_{12}H_{11}N^{+\cdot}]$, 168 (64.4) $[C_{12}H_{10}N^+]$, 105 (7.5) $[C_7H_5O^+]$, 77 (9.4) $[C_6H_5^+]$.

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