sodium sulfate. The mixture was filtered through Celite and centrifuged to remove colloidal copper. The dichloromethane was removed under reduced pressure to yield 29.4 g (86%), which contained no impurities detected by GLC or ^{1}H NMR. Anal. Calcd for $C_9H_{18}O_4$: C, 56.82; H, 9.54. Found: C, 56.79; H, 9.72. Distillation of 28.1 g at 0.35 torr gave fractions of 14.7 g (bp 49-52 °C) and 9.1 g (bp 52-53 °C) for an 85% recovery. Anal. Found: C, 56.66; H, 9.53. **2**: IR (neat) 2982, 2937, 2900, 1735, 1445, 1373, 1310, 1190, 1110, 1060 cm^{-1}, ^{1}H NMR ($CDCl_3$/Me_4Si) δ 1.18 (t, J = 7 Hz, 6 H), 1.25 (t, J = 7 Hz, 3 H), 2.63 (d, J = 6 Hz, 2 H), 3.59 (q, J = 7 Hz, 2 H), 3.63 (q, J = 7 Hz, 2 H), 4.15 (q, J = 7 Hz, 2 H), 4.95 (t, J = 6 Hz, 1 H).

(Ethoxycarbonyl)malondialdehyde (1). To a flame-dried, 200-mL recovery flask was added 2.70 g (56 mmol; Aldrich) of 50% sodium hydride/oil dispersion. After the flask was purged with nitrogen, the oil was rinsed off with three 15-mL portions of ether; then 50 mL of fresh ether was added. A condenser was fitted to the flask under nitrogen, and the magnetically stirred slurry was cooled in an ice bath. Ethyl formate (34.8 g, 470 mmol; Aldrich) was added by syringe, followed by 8.84 g (46.5 mmol) of **2** dissolved in 25 mL of ether, added dropwise by syringe over 2 h. The reaction mixture was stirred for 1 day at 0 °C and then for 1 day at room temperature. (^{1}H NMR showed no improvement at the higher temperature.) It was poured into 100 mL of ice water and extracted with three 50-mL portions of ether, which were discarded. Acidification to pH 3 with 4.5 mL of concentrated HCl and extraction with three 50-mL portions of dichloromethane afforded (after drying the combined organic phase over anhydrous sodium sulfate and removal of solvent at reduced pressure) 5.10 g (75%) of **1**. Anal. Calcd for $C_6H_8O_4$: C, 50.00; H, 5.60. Found: C, 50.30; H, 5.72. The ^{1}H NMR spectrum was the same as that of distilled material. Distillation gave a 59% recovery, bp 30-32 °C (0.35 torr). Anal. Found: C, 49.70; H, 5.73. **1**: IR (neat) 3700-2500, 2986, 1700, 1645, 1580, 1240, 1103, 1015, 938, 763, 750 cm^{-1}; ^{1}H NMR ($CDCl_3$/Me_4Si) δ 1.30 (t, J = 7 Hz, 3 H), 4.30 (q, J = 7 Hz, 2 H), 9.13 (s, 2 H), 12.4 (br s, 1 H); UV (EtOH) λ_{max} 212 nm (ε 3500), 245 (6200), 263 (5400, sh).

Registry No. **1**, 80370-42-9; **2**, 10601-80-6; **3**, 623-47-2; **4**, 1001-26-9; copper(I) triflate, 42152-44-3.

Formaldehyde Semicarbazone

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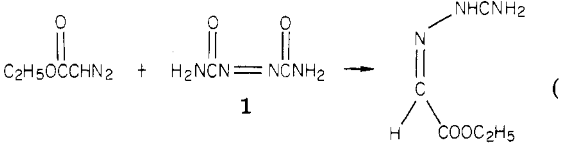
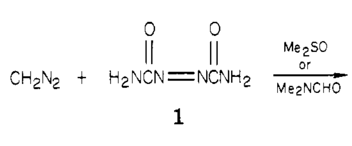
Our recent interest in the reactions of diazo compounds with azodicarbonamide (**1**)[2] has prompted us to examine the reaction between diazomethane and azodicarbonamide (**1**). Our initial studies of ethyl diazoacetate and **1** provided the Z isomer of the semicarbazone of glyoxylic acid (**2**; eq 1). We examined the reaction of diazomethane with **1** in order to initiate studies of the generality and ultimately the mechanism of this intriguing reaction. We now report that the product is formaldehyde semicarbazone and that this is the first time this derivative of formaldehyde has actually been prepared.



1 2 (1)

Results and Discussion

When a solution of diazomethane (substantial excess) is added to azodicarbonamide (**1**) in either Me_2SO or Me_2NCHO and the reaction mixture is allowed to stand overnight, a substance, mp 120-121 °C, is obtained after silica gel chromatography and recrystallization from ethanol. The properties of this substance, as described below, in addition to its formation in a reaction known to provide the semicarbazone skeleton, leave no doubt that it is the heretofore unknown formaldehyde semicarbazone (**3**; eq 2).



1 3 (2)

The analyses and mass spectrum (M^+ at m/e 87) are consistent with the formula $C_2H_5N_3O$. Major peaks at m/e 43 and 44 represent cleavage of the molecule at the central C-N bond, and a peak at 60 represents loss of HCN, all consistent with the assigned semicarbazone structure.[3] The ^{1}H NMR spectrum (Me_2SO-d_6) shows an AB double doublet (CH_2) at δ 6.8 and 6.1 with $^2J_{HH}$ = 12 Hz, a broad singlet (NH_2) at δ 6.2 which overlaps one of the peaks centered at δ 6.1, and a broad singlet at δ 10.0 (NH). The ^{13}C NMR spectrum shows two peaks at 156.7 ppm ($>C{=}O$) and 130.4 ppm ($CH_2{=}$; relative to Me_4Si). These NMR resonances and assignments are completely consistent with those of semicarbazones previously reported.[2,4,5] For example, acetaldehyde semicarbazone shows the CH resonances (^{1}H NMR spectrum) at δ 7.00 and 6.47 (for the cis and trans isomers), ethyl glyoxylate semicarbazone shows the NH_2 protons at δ 6.55 and the NH proton at δ 10.95, and isobutyraldehyde and ethyl glyoxylate semicarbazones show the $>C{=}O$ carbon (^{13}C NMR spectrum) at 150-156 ppm and the Shiff base carbon ($>C{=}N{-}$) at 130 ppm for the latter and 159 ppm for the former. This apparent large difference between a $CH_2{=}N$ carbon and a monosubstituted i-PrCH=N carbon is reasonable, since it is known that terminal CH_2 vinyl carbon atoms absorb 10-40 ppm to higher field than substituted vinyl carbon atoms.[6]

The UV spectrum of **3** [λ_{max} (CH_3CN) 227 nm (log ε 3.73)] is consistent with those of other semicarbazones,[7] such as acetone semicarbazone [λ_{max} (CH_3CN) 223 nm (log ε 4.11)]. Finally, the infrared spectrum (KBr disk) [$\tilde{\nu}$ 3310, 3260, 3200, 3090, 1660, and 1581 cm^{-1}] is also consistent with the assigned structure.[8]

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(2) Pomerantz, M.; Bittner, S. *J. Org. Chem.* **1980**, *45*, 5390.

(3) Beher, D.; Sample, S. D.; Djerassi, C. *Chem. Ber.* **1966**, *99*, 2284. Nakata, H.; Tatematsu, A. *Chem. Commun.* **1967**, *208*. Blythin, D. J.; Waight, E. S. *J. Chem. Soc. B* **1967**, 583.

(4) Karabatsos, G. J.; Vane, F. M.; Taller, R. A.; Hsi, N. *J. Am. Chem. Soc.* **1964**, *86*, 3351.

(5) Naulet, N.; Filleux, M. L.; Martin, G. J.; Pornet, J. *Org. Magn. Reson.* **1975**, *7*, 326.

(6) Breitmaier, E. "^{13}C NMR Spectroscopy", 2nd Ed.; Verlag Chemie: Weinheim, Germany, 1978.

(7) Gillam, A. E.; Stern, E. S. "An Introduction to Electronic Absorption Spectroscopy in Organic Chemistry"; Edward Arnold: London, 1954; Chapter 5.

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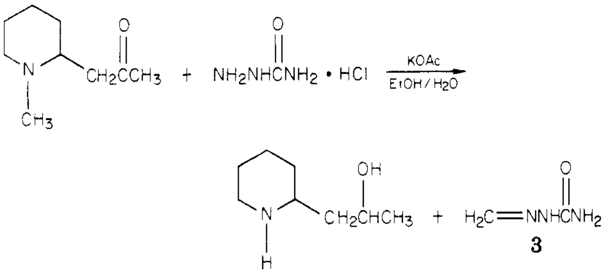
Thus, as the physical data prove, we have prepared formaldehyde semicarbazone (**3**). Further, **3** is readily hydrolyzed to formaldehyde. This was shown by mixing the formaldehyde semicarbazone (**3**) with 2,4-dinitrophenylhydrazine in Me_2SO, adding acid and water, and observing a rapid precipitation of formaldehyde 2,4-dinitrophenylhydrazone, identified by its melting point, mixed melting point with authentic material, and its TLC R_f value. In addition, prolonged heating of **3** in protic solvents results in loss of **3**.

Formaldehyde semicarbazone (**3**) is listed in tables of aldehyde derivatives as having a melting point of 169 °C.[9] This value is most likely wrong, since the compound which we have prepared (mp 120–121 °C) is clearly **3**. A search of the literature, through *Chemical Abstracts*, reveals a single report of the preparation and isolation of formaldehyde semicarbazone (**3**).[10] The compound (mp 169 °C) was isolated from the reaction of 1-(*N*-methyl-α-piperidyl)propan-2-one with semicarbazide hydrochloride and potassium acetate in aqueous ethanol (see eq 3) and was recrystallized from hot water. The only evidence presented for the structure of **3** was its elemental analysis and the production of a reduced, demethylated product (eq 3). Further, since it has been known for a great many years that **3** cannot be prepared by the reaction of formaldehyde (formalin solution) with semicarbazide,[10-13] there was no other way, until the present work, to prepare **3** and to obtain the melting point of the substance (**3**) whose structure has been authenticated by modern techniques. As a result, the 169 °C melting point was never questioned.



(3)

It is thus clear, until the structure of the 169 °C melting point compound is elucidated, that the reaction reported here is currently the only way to prepare formaldehyde semicarbazone (**3**) and that the tables of aldehyde derivatives should be corrected to reflect the 120–121 °C melting point (or eliminate the entry completely since it is not a suitable derivative for the identification of formaldehyde).

Experimental Section

The melting point was obtained on a Thomas-Hoover melting point apparatus and is corrected. The ^1H NMR spectrum was obtained on a Varian T-60 (60 MHz) or Nicolet NT-200 wide-bore (200 MHz) spectrometer with Me_4Si internal standard as a solution in Me_2SO-d_6. The ^{13}C NMR spectrum was obtained on a JEOL FX90Q instrument at 22.6 MHz in Me_2SO-d_6 using Me_4Si internal standard and on a Nicolet NT-200 spectrometer at 50.3 MHz in Me_2SO-d_6 as solvent and standard (39.5 ppm). The UV spectra were obtained on a Cary 219 spectrometer, the IR spectrum on a Perkin-Elmer 751 spectrometer, and the mass spectrum on a DuPont 321 mass spectrometer coupled to a Riber 400 data system. The C, H, and N analysis was by Galbraith Laboratories, Knoxville, TN.

Formaldehyde Semicarbazone (3). Azodicarbonamide (**1**; 1.0 g, 8.6 mmol) was dissolved in 100 mL of warm Me_2NCHO (or Me_2SO), and after cooling to room temperature, the diazomethane[14] prepared from 10.0 g (97 mmol) of *N*-methyl-*N*-nitrosourea[15] in ether was added. The mixture was stirred overnight at room temperature, after which the solvent was removed in vacuo. The yield of **3**, estimated from the ^1H NMR spectrum of the crude product using nitromethane as internal standard, was about 60%.[16] Chromatography on silica gel (2.5 × 28 cm column) using $CHCl_3$, then 1, 2, and 4% methanol–chloroform, provided formaldehyde semicarbazone (**3**), which was further purified by recrystallization from ethanol, mp 120–121 °C. Anal. Calcd for $C_2H_5N_3O$: C, 27.59; H, 5.79; N, 48.25. Found: C, 27.77; H, 5.86; N, 48.05. Spectral data are presented under Results and Discussion.

Hydrolysis of Formaldehyde Semicarbazone (3). A solution of 16 mg (0.18 mmol) of **3** in 0.5 mL of Me_2SO was added to 1 mL of a saturated solution of 2,4-dinitrophenylhydrazine in Me_2SO, followed by ca. 0.03 mL of concentrated sulfuric acid. About 0.05 mL of water was added, and a yellow precipitate formed rapidly. The mixture was warmed briefly to 40 °C, allowed to stand overnight, and filtered (14 mg, 0.068 mmol, 38% yield; mp 157–159 °C). The solid was washed with water, and then ether was passed through the filter to dissolve the formaldehyde 2,4-dinitrophenylhydrazone and remove insoluble impurities. The ether was removed in vacuo, and the yellow solid was recrystallized from methanol to give a product with mp 163–165 °C, mmp 163–165 °C (lit.[9] 166 °C). The TLC R_f value (silica gel, MeOH) was the same as authentic formaldehyde 2,4-dinitrophenylhydrazone.

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Registry No. **1**, 123-77-3; **3**, 14066-69-4; diazomethane, 334-88-3; formaldehyde 2,4-dinitrophenylhydrazone, 1081-15-8.

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[8] Rao, C. N. R. "Chemical Applications of Infrared Spectroscopy;" Academic Press: New York, 1963.

[9] See, for example, "Handbook of Tables for Organic Compound Identification", 3rd Ed.; Rappoport, Z., Ed.; CRC Press: Cleveland, 1977.

[10] Hess, K.; Eichel, A.; Uibrig, C. *Ber. Dtsch. Chem. Ges.*, **1917**, *50*, 351; see also *J. Chem. Soc.* **1917**, 352, for an abstract.

[11] Thiele, J.; Bailey, J. *Justus Liebigs Ann. Chem.* **1898**, *303*, 91.

[12] Michael, A. *J. Am. Chem. Soc.* **1919**, *41*, 393.

[13] Johnston, F. L. U.S. Patent 2 308 696, 1943; *Chem. Abstr.* **1943**, *37*, 3858[6].

[14] Arndt, F. "Organic Syntheses"; Wiley: New York, 1943; Collect. Vol. II, p 165.

[15] Arndt, F. ref 14, p 461.

[16] NMR estimated yields varied between 54 and 71%.