



A Publication
of Reliable Methods
for the Preparation
of Organic Compounds

Working with Hazardous Chemicals

The procedures in *Organic Syntheses* are intended for use only by persons with proper training in experimental organic chemistry. All hazardous materials should be handled using the standard procedures for work with chemicals described in references such as "Prudent Practices in the Laboratory" (The National Academies Press, Washington, D.C., 2011; the full text can be accessed free of charge at http://www.nap.edu/catalog.php?record_id=12654). All chemical waste should be disposed of in accordance with local regulations. For general guidelines for the management of chemical waste, see Chapter 8 of Prudent Practices.

In some articles in *Organic Syntheses*, chemical-specific hazards are highlighted in red "Caution Notes" within a procedure. It is important to recognize that the absence of a caution note does not imply that no significant hazards are associated with the chemicals involved in that procedure. Prior to performing a reaction, a thorough risk assessment should be carried out that includes a review of the potential hazards associated with each chemical and experimental operation on the scale that is planned for the procedure. Guidelines for carrying out a risk assessment and for analyzing the hazards associated with chemicals can be found in Chapter 4 of Prudent Practices.

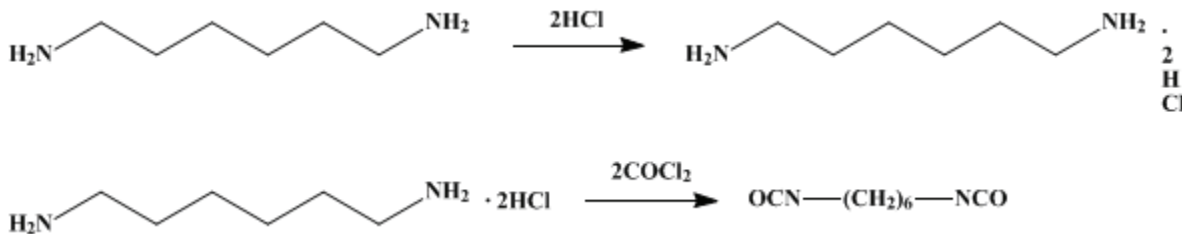
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These paragraphs were added in September 2014. The statements above do not supersede any specific hazard caution notes and safety instructions included in the procedure.

Organic Syntheses, Coll. Vol. 4, p.521 (1963); Vol. 31, p.62 (1951).

HEXAMETHYLENE DIISOCYANATE

[Isocyanic acid, hexamethylene ester]



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1. Procedure

Caution! Hexamethylenediamine, hexamethylene diisocyanate, and phosgene are highly toxic. Exposure to vapors or solutions containing these materials should be avoided. All operations should be conducted in a hood.

A. *Hexamethylenediammonium chloride*. To a solution of 116 g. (1.0 mole) of hexamethylenediamine (Note 1) in 145 ml. of methanol in a 1-l. beaker is added slowly from a dropping funnel 175 ml. of concentrated hydrochloric acid (sp. gr. 1.19). The mixture is well stirred during the addition and cooled externally to keep the contents below 30°. The hexamethylenediammonium chloride is then precipitated by adding the solution slowly with stirring to approximately 2 l. of acetone. The precipitate is collected on a Büchner funnel, washed with 100 ml. of cold acetone, and dried in a vacuum oven at 75° for 12–18 hours (Note 2). The yield of dry product amounts to 170–187 g. (90–99%), m.p. 243–246° (Note 3).

B. *Hexamethylene diisocyanate*. A suspension of 94.5 g. (0.50 mole) of finely powdered hexamethylenediammonium chloride in 500 ml. of anhydrous redistilled amylbenzene (or tetralin) (Note 4) is prepared in a 1-l. three-necked flask fitted with an efficient mechanical stirrer (Note 5), a water-cooled reflux condenser, a thermometer, and a phosgene inlet tube (Note 6) extending well below the surface of the suspension. Stirring is started, the mixture is heated to 180–185° (Note 7), and gaseous chlorine-free phosgene (Note 8) is delivered to the mixture at a rate of about 33 g. (0.33 mole) per hour. Hydrogen chloride and excess phosgene escape through the condenser. The temperature is carefully maintained between 180° and 185°; after 8–15 hours (Note 9) solution of the hexamethylenediammonium chloride is essentially complete and hydrogen chloride is no longer evolved (Note 10). The reaction mixture is then filtered through a suction filter, and the filtrate is distilled at reduced pressure through a fractionating column, giving amylbenzene, b.p. 65–75° /10 mm. (Note 11), and 70–80 g. (84–95%) of hexamethylene diisocyanate boiling at 120–125° /10 mm. (92–96° /1 mm., 108–111° /5 mm.); n_D^{20} 1.4585; d_4^{20} 1.0528 (Note 12).

2. Notes

1. Hexamethylenediamine may be obtained from the Polychemicals Department, E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware. Usually the commercial product is a 70% aqueous solution from which the water may be distilled at atmospheric pressure. The residue is suitable for preparing the dihydrochloride.

2. Thorough drying of the hydrochloride is essential to the success of the next step. Overnight drying in a vacuum oven at 70–100° is effective. The dry salt is not appreciably hygroscopic, but it should be preserved in a well-stoppered bottle until used.

3. This salt shows a marked tendency to sublime at and above 200°.
4. It is preferable to add the hexamethylenediaomnium chloride in three portions. This modification facilitates stirring and prevents clumping of the solid.² Commercial [amylbenzene](#) is dried by distillation, and the fraction boiling at 184–194° is collected. This solvent has been withdrawn from the market (1950) and hence [tetralin](#) may be substituted. Commercial [tetralin](#) is washed with [ferrous sulfate](#) solution and distilled; the fraction boiling at 202–206° is used. [o-Dichlorobenzene](#) also has been recommended as a solvent.³ When the latter was employed,² it was found advisable to use recovered material, since it contained some component that acted as a solvent for the hydrochloride. The [phosgene](#) was absorbed more rapidly, and the reaction was completed in only 9 hours.
5. Efficient agitation of the gas-liquid-solid reaction mixture is conducive to a high rate of reaction. The use of a reaction flask modified with creases⁴ has given good results.
6. The end of the inlet tube should have a very coarse fritted glass disk in order to promote rapid reaction. A tube with a bulb in which many fine holes have been blown may also be used, but the reaction time is longer. If the inlet tube becomes clogged, it may be cleaned quickly by removing it from the reaction flask and dipping in warm [cresol](#), which dissolves any polyhexamethylene urea that may form. The tube is then rinsed with [amylbenzene](#) or [tetralin](#) and replaced in the reaction flask.
7. The temperature of the reaction mixture should be maintained between 180° and 185° in order to obtain as rapid a reaction as possible. Higher temperatures lead to the formation of polyhexamethylene urea. A run carried out at the boiling point of [tetralin](#) (206°) gave an 84% yield of polymer.
8. [Phosgene](#) is available from the Niagara Chlorine Products Co., Inc., Lockport, New York, or the Matheson Co., Inc., Rutherford, New Jersey. When [phosgene](#) containing small amounts of [chlorine](#) is used, the reaction appears to proceed normally but the product and recovered solvent are contaminated with chlorine-containing impurities. [Chlorine](#) in [phosgene](#) can be detected by bubbling a stream of the gas rapidly through clean [mercury](#). [Chlorine](#) reacts with and discolors the [mercury](#), whereas pure [phosgene](#) leaves the [mercury](#) unchanged. If [chlorine](#) is present, it may be removed by bubbling the [phosgene](#) through two wash bottles containing cottonseed oil.
9. The time required for complete reaction is dependent on the reaction temperature, on the design of the [phosgene](#) inlet tube, on the efficiency of agitation, and on the rate of [phosgene](#) addition. It is important that the reaction be continued until practically all the [hexamethylenediammonium chloride](#) has disappeared. If unreacted amine salt is present, it has a tendency to sublime with the diisocyanate during distillation.
10. When moist air is blown through a glass tube held at the end of the condenser, across the current of [phosgene](#) containing [hydrogen chloride](#), the fogging typical of [hydrogen chloride](#) gas in a moist atmosphere is produced. Pure [phosgene](#) gives no visible effect under similar conditions.
11. The recovered solvent is suitable for succeeding preparations. If [tetralin](#) is used as the reaction medium, it is recovered as the low-boiling fraction, b.p. 60–70°/8 mm.
12. If the product contains [chlorine](#) as indicated by the alcoholic [silver nitrate](#) test, it may be purified by adding a small amount of anhydrous [calcium oxide](#) (0.5 g. per 50 g. of product) and redistilling under reduced pressure.

3. Discussion

[Hexamethylene diisocyanate](#) has been prepared by the action of [phosgene](#) on [hexamethylenediammonium chloride](#)⁵ or on [hexamethylenediammonium carbonate](#).⁶ Metal chlorides such as those of [cobalt](#), [iron](#), [mercury](#), or [zinc](#) have been stated to promote the reaction.³ It has been claimed⁷ that the vapor-phase reaction of an hexamethylenediamine-toluene solution with [phosgene](#) at 280–300° affords an 80% yield of the diisocyanate.

References and Notes

1. E. I. du Pont de Nemours and Company, Wilmington, Delaware.
2. Allen, Private communication.
3. Burgoine and New, Imperial Chemical Industries, Ltd., Brit. pat. 574,222 [*C. A.*, **42**, 7788 (1948)].

4. Morton, Darling, and Davidson, *Ind. Eng. Chem., Anal. Ed.*, **14**, 734 (1942).
 5. Farlow, E. I. du Pont de Nemours and Company, U. S. pat. 2,374,340 [*C. A.*, **39**, 3555 (1945)].
 6. Smith, P. B. 7416, *Synthetic Fiber Developments in Germany*, p. 47, Textile Research Institute, Inc., New York, 1946.
 7. Mashio and Nomachi, *J. Chem. Soc. Japan, Ind. Chem. Sect.*, **56**, 289 (1953) [*C. A.*, **48**, 10634 (1954)].
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Appendix
Chemical Abstracts Nomenclature (Collective Index Number);
(Registry Number)

hexamethylenediaomnium chloride

polyhexamethylene urea

hexamethylenediamine-toluene

hydrogen chloride,
hydrochloric acid (7647-01-0)

methanol (67-56-1)

iron (7439-89-6)

silver nitrate (7761-88-8)

ferrous sulfate (13463-43-9)

mercury (7439-97-6)

acetone (67-64-1)

chlorine (7782-50-5)

zinc (7440-66-6)

phosgene (75-44-5)

cresol (95-48-7)

calcium oxide

Tetralin (119-64-2)

Amylbenzene (538-68-1)

cobalt (7440-48-4)

Hexamethylene diisocyanate,
Isocyanic acid, hexamethylene ester (822-06-0)

hexamethylenediamine (124-09-4)

hexamethylenediammonium chloride

hexamethylenediammonium carbonate

o-dichlorobenzene (95-50-1)