

N-Azidoamines and –Amides as Possible Synthons

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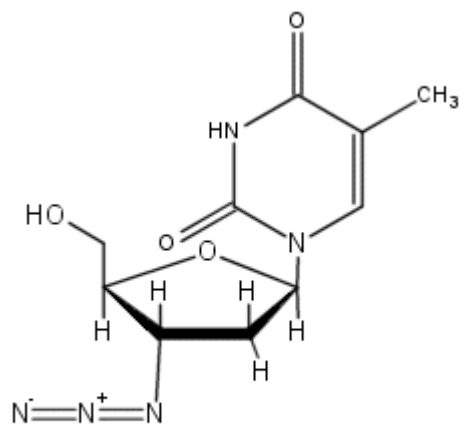
Georgeville , Quebec , Canada

May 27 , 2004

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Introduction

The use of the unusual nucleoside azidothymidine (AZT , zidovudine) in antiviral chemotherapy gave me the idea for preparing N-azido compounds (amines and amides) for possible use as synthons in organic syntheses .



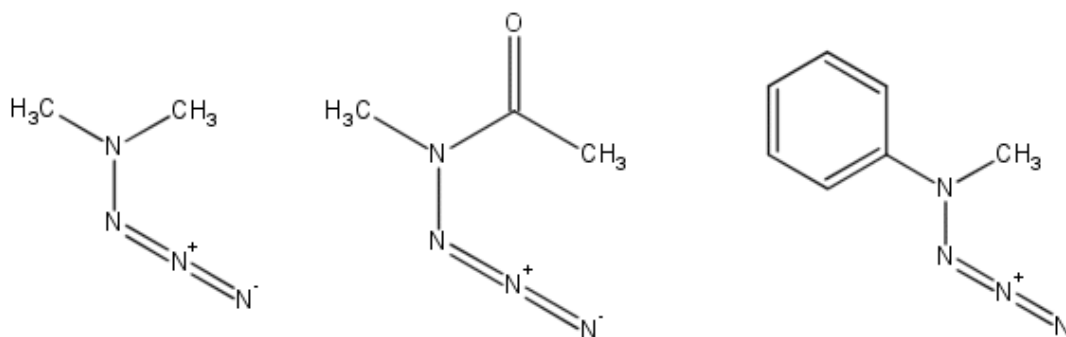
Azidothymidine

If C-azides such as AZT were reasonably stable , and could be prepared and handled with relative safety , what about N-azides , such as N-azidoamines and –amides , acyclic and cyclic , aliphatic , aromatic , and possibly even heterocyclic ? A sampling of such N-azido compounds is shown on the following page .

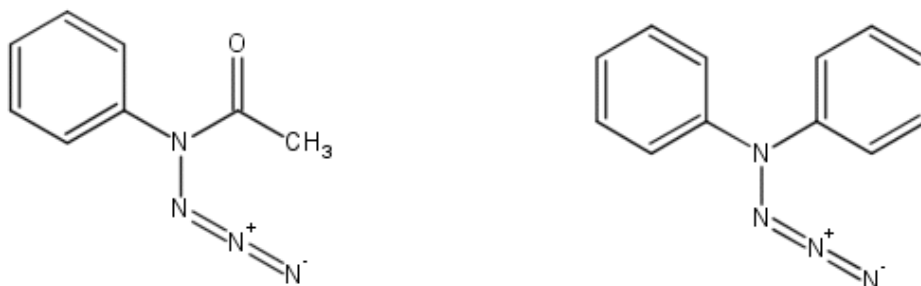
The interest in such novel compounds would lie in their possible use as synthons in organic reactions . The clustering of the four nitrogen atoms in the molecules suggests that upon pyrolysis , with or without catalysis , these four nitrogen atoms might be expelled as the highly stable two nitrogen molecules . The carbon fragment or fragments might then react with either themselves or with other suitable substrate molecules present in the reaction mixture , such as an olefin , for example .

The carbon fragments would be liberated in the reaction as either free radicals of some sort or other , or as ionic intermediates , depending on

their inherent stability and stabilizing factors in the reaction medium .

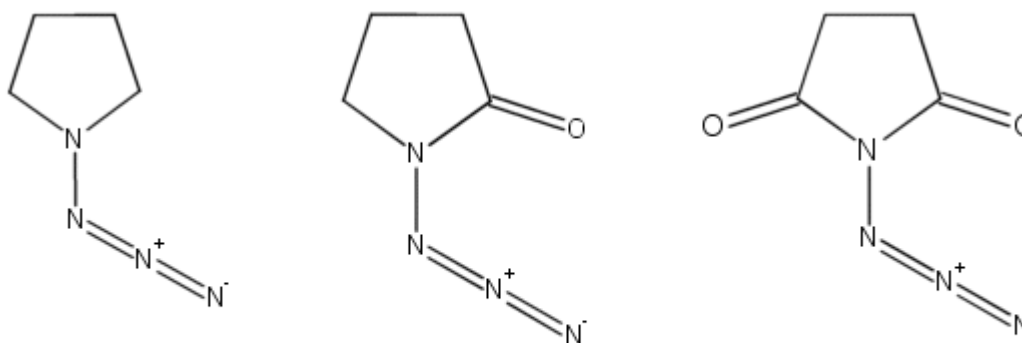


N-azidodimethylamine N-azido-N-methylacetamide N-azido-N-methylaniline



N-azidoacetanilide

N-azidodiphenylamine

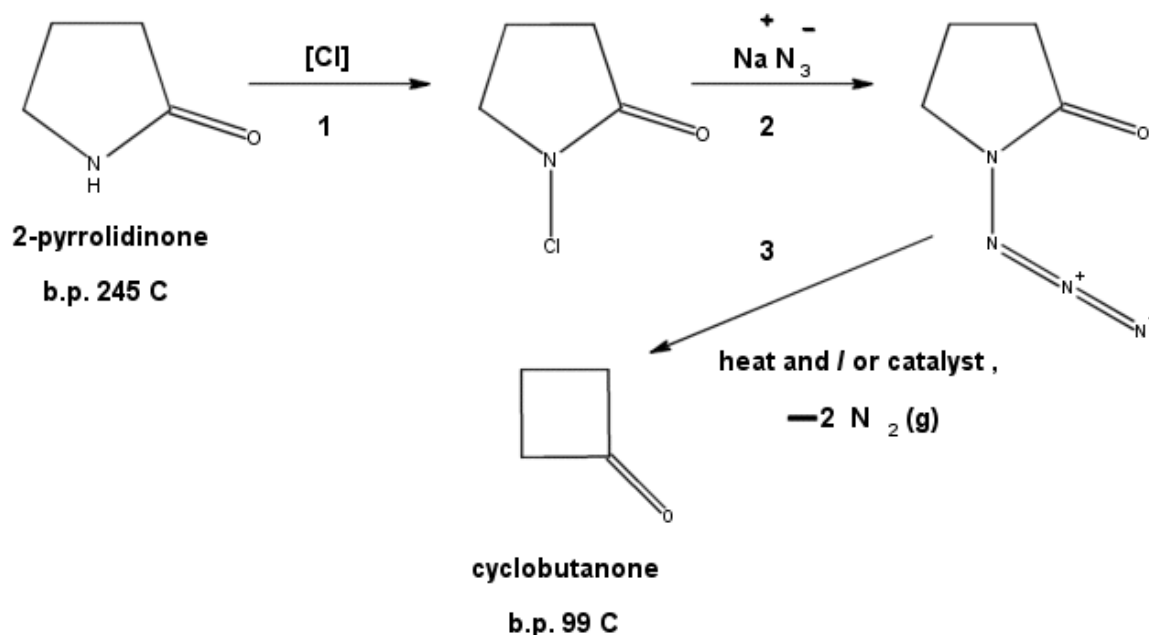


N-azidopyrrolidine

N-azidopyrrolidinone

N-azidosuccinimide

An example of an **intramolecular** reaction of an N-azidoamide :



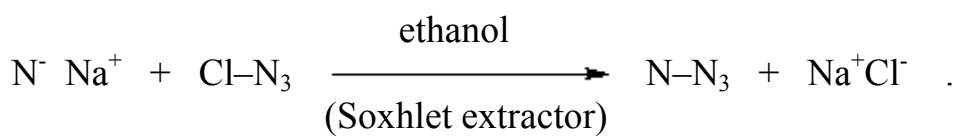
In step 1 , the amide is 2-pyrrolidinone (“pyrrolidone”) , an inexpensive industrial bulk chemical . N-Haloamides (and n-haloamines) are well known materials , and can generally be prepared fairly easily by treatment of the parent amide with hypohalite (such as sodium hypochlorite , NaOCl , “Javelle water”) , or with a combination of alkali and elementary halogen (chlorine or bromine) . Another possibility would be to treat the amide with a powerful deprotonating agent , such as lithium or sodium hydride or alkoxide , followed by addition of the halogen (see Note 1, page 14) .

In step 2 , the N-azidopyrrolidinone is prepared by treatment of the N-chloropyrrolidinone with sodium azide , NaN₃ . I am assuming that the azide anion is sufficiently nucleophilic to displace the chlorine from the amide . Actually , this would have to be a **two-step** process , because the N-Cl bond has the polarity , N δ^- – Cl δ^+ :



The intermediate chlorine azide , Cl-N₃ , is a known compound ; it and its

relatives are called “pseudohalogens”, because the azide anion behaves chemically somewhat like a halogen atom in them. If the N^- of the amide reacts with the Cl part of ClN_3 , the starting products are regenerated. If it reacts with the azide part of ClN_3 , the N-azidoamide will be produced. The N–Cl bond in the chloroamide is quite labile, whereas the N– N_3 bond should be stronger and less labile. We anticipate the second reaction to be:



Sodium azide is sparingly soluble in ethanol – about 3 g/L at room temperature – so a useful technique in this case might be to extract it continuously into the reaction flask with hot solvent in a **Soxhlet extractor**. Vigorous mechanical stirring of the contents of the flask is recommended, to avoid a violent “bumping” of the refluxing reaction mixture, caused by the suspended particles of sodium chloride by-product.

In step 3, the N-azidopyrrolidinone is decomposed to the carbon fragment and two nitrogen molecules. This might be accomplished thermally, by pyrolysis, with or without a catalyst. Unaided and unmoderated, the decomposition of the N-azido compounds could proceed in an uncontrolled, **explosive** manner. Stabilization of the intermediate carbon fragment is essential to prevent it from rapidly “unzipping” into smaller gaseous molecules. A **metal surface** might help to stabilize a free radical carbon fragment such as $\text{CH}_2\text{-}\dot{\text{C}}\text{H}_2\text{CH}_2\text{-C(=O)}$, with the orbitals containing the free radicals overlapping with the metallic bond (“conduction band”) of the metal surface, containing the free electrons (which are also singlet electrons). Transient sigma MO carbon–metal bonds could form, helping to sustain the carbon fragment and prolong its lifetime.

A **polar solvent** could stabilize an ionic intermediate such as $\text{CH}_2\text{-}\text{CH}_2\text{CH}_2\text{-C}^+\text{=O}$, giving it a chance to cyclize to cyclobutanone. It is actually rather difficult to close four-atom rings, and telomers, polymers, and large ring compounds may preferentially form. A variety of polar solvents are available to the researcher, including the often overlooked

propylene carbonate (PC) , which can dissolve appreciable amounts of inorganic salts , and has been used in electrochemical studies :

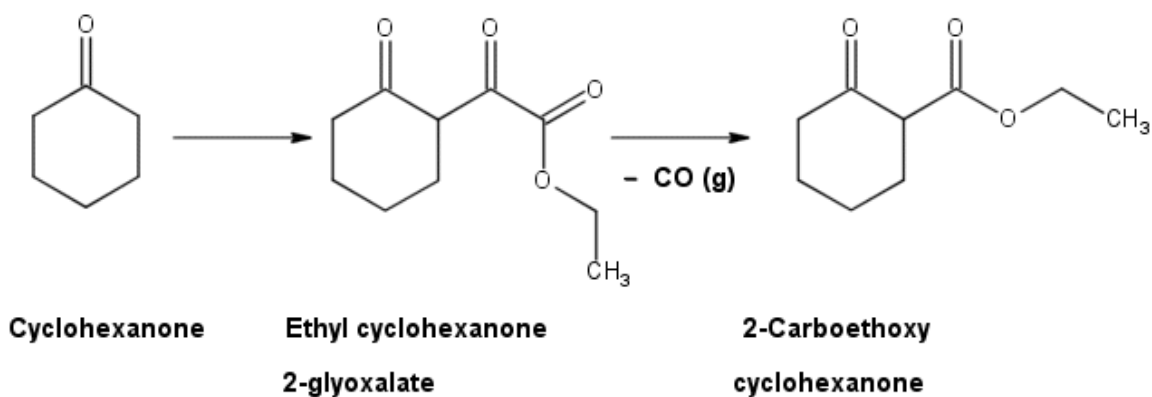
Selected Properties of Several Polar Solvents

<u>Solvent</u>	<u>Dielectric Constant</u>	<u>Dipole Moment</u>	<u>Boiling Point</u>
Water	78.5	1.84 debye	100 C
Propylene Carbonate	65.1	4.98	240
Dimethyl Sulfoxide	49	3.96	189
Dimethyl Formamide	36.7	3.86	152
Nitromethane	38.6	3.46	101
Acetonitrile	36.2	3.92	82

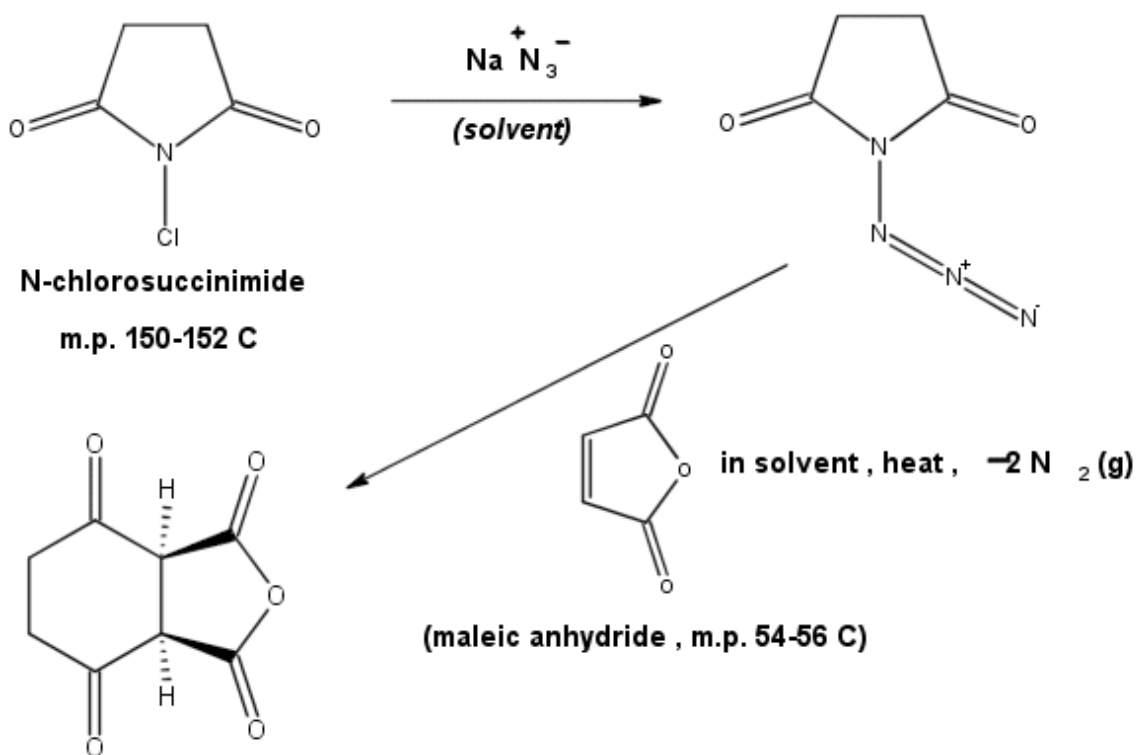
- R. Jasinski , “Electrochemistry and Application of Propylene Carbonate” , Adv. Electrochemistry Electrochem. Eng. , vol. 8 , pp. 253-335 , P. Delahay and C.W. Tobias (eds.) , Wiley Interscience , New York , 1971 .

If cyclization of the stabilized carbon fragment to cyclobutanone was successful , the latter product (b.p. 99 °C) could be distilled cleanly from the PC solvent (b.p. 240 °C) . The PC would also help to minimize the formation of telomers and polymers . A catalytic surface might still be helpful , even with the highly polar PC solvent . The addition of a small quantity of freshly ground soda-lime glass and a catalytic quantity of iron powder to the pyrolysis of a ketoester has been found to assist in its decarbonylation (see the sketch at the top of the following page) . Metal powders such as iron , nickel , copper , and possibly even graphite could be tried as catalysts .

The carbon fragment(s) might be intercepted by a reactive substrate molecule such as an olefin , resulting in its or their addition to it . If **cyclizations** with olefins could be accomplished , such reactions would be a useful supplement to other such “classical” cyclizations , such as the Diels-Alder reaction . An example of such a possible cyclization with an N-azidoamide is illustrated on the next page .



- H.R. Snyder , L.A. Brooks , and S.H. Shapiro , “Pimelic Acid” , pp. 531-534 in Organic Syntheses , Coll. Vol. 2 , A.H. Blatt et al. (eds.) , John Wiley , New York , 1943 .



As in the previous example , the use of a highly polar solvent such as PC , and of a finely divided catalytic powder such as ground glass and/or iron powder might be necessary to achieve a smooth , controllable , and safe

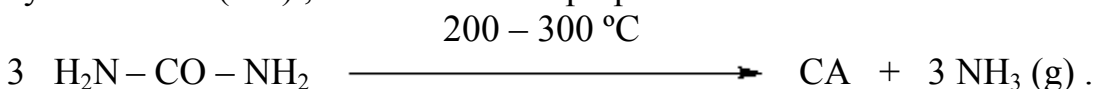
decomposition of the N-azidoamide in the presence of the receptor substrate molecule .

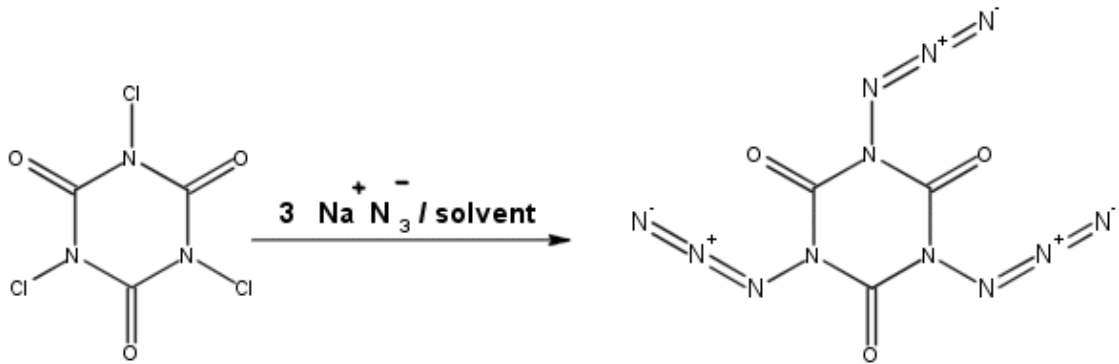
For the record , I'm now going to repeat my "standard warning" to any interested persons :

I cannot overemphasize the great need for **safety** if the following procedures – and any others mentioned in this text – are carried out . The reader must assume full responsibility for the safe manipulation of the reagents cited and in carrying out any actual trial runs . Of course , I expect all my readers are mature , responsible chemists , and are well versed in chemical theory and practice . As a basic minimum precaution , however , I would suggest that no more than semi-micro quantities of reagents (a gram or less) be utilized , that the experiments be carried out in a clean , vacant area with air aspiration (an empty fume hood) , and that protective equipment be deployed by the researcher , **especially** eye protection (the latter I can personally certify !) .

Clearly , the N-azidoamines and –amides are potentially very hazardous , explosive substances . However , I am reminded of the familiar organic chemistry reagent **diazomethane** , CH_2N_2 , which is highly toxic and explosive (and which I have prepared substantial quantities of , without incident , in my younger days) . If the proper precautions are taken , even dangerous chemicals can be safely used by researchers to carry out many new and useful reactions , as with diazomethane . This is undoubtedly the case with the N-azidoamines and –amides . They might be particularly valuable synthons , as they have the potential to build and modify the carbon skeletons of molecules .

They might also have a direct and important **practical** application which takes advantage of their potentially unstable nature as explosives ! In the sketch on the following page I have outlined the preparation of a possible new high explosive compound , based on an N-azidoamide . The starting material , trichloroisocyanuric acid , is manufactured on a large scale from cyanuric acid (CA) , which in turn is prepared from the bulk chemical urea :

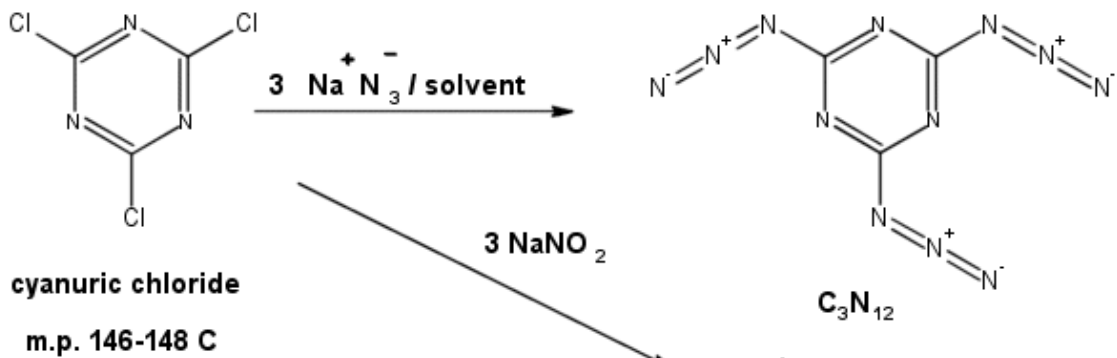
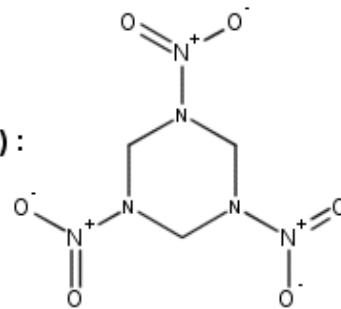




trichloroisocyanuric acid

m.p. 249-251 C

cf. cyclonite (in RDX , Semtex , or C4) :

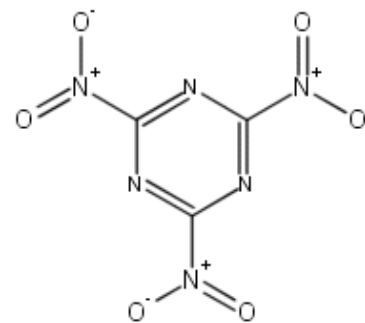


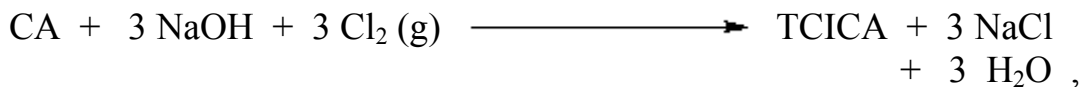
cyanuric chloride

m.p. 146-148 C

3 NaNO₂

C₃N₁₂

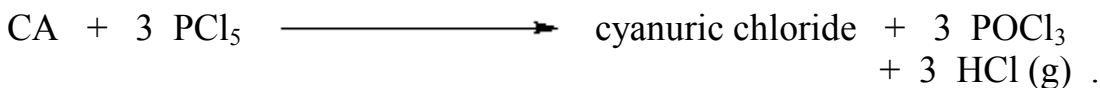




where “TCICA” is trichloroisocyanuric acid , shown on the previous page .

Trichloroisocyanuric acid was first manufactured and marketed in bulk as a domestic and industrial disinfectant , especially as a swimming pool treatment chemical , in 1958 . It is still available in tablet form for that application . It is also available as a pure chemical reagent , for example from the Aldrich Chemical Company .

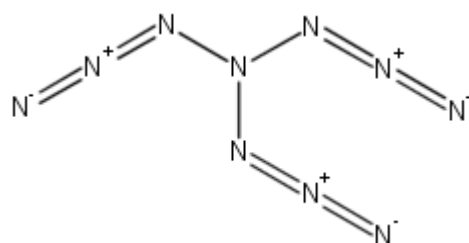
I have also shown on the previous page a couple of possible functionalizations of the related compound , cyanuric chloride , which is related to cyanuric acid , and is prepared from the latter by chlorination :



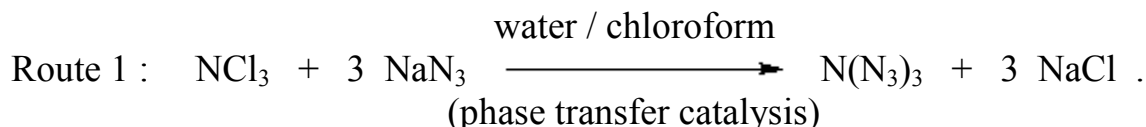
The N–Cl bond in cyanuric chloride (as in trichloroisocyanuric acid) is quite labile , and its chlorine atoms can be readily displaced by nucleophiles such as ammonia ; in that case , triaminocyanuric acid , **melamine** , is produced . Melamine is used in some thermoset plastics , such as melamine-formaldehyde . I don't know if azide or the other anion , nitrite , is sufficiently nucleophilic to accomplish the desired displacement of the chlorines from the heterocyclic rings , to produce the potential new explosive azido and nitro compounds .

Although terrorists are giving explosives a bad reputation these days , explosives are in fact an extremely important type of industrial organic chemical commodity , being invaluable in the mining and construction industries , for example . Obviously , I wouldn't recommend an investigation of these latter reactions (outlined above on page 8) to either “casual” or amateur chemists with a basement laboratory , nor even to seasoned academics , but only to experienced industrial researchers in the field of explosives research and development , if they were interested in these new ideas . Such experts might find some merit in them **safely** !

Here is another idea concerning azides, this time in the field of inorganic chemistry. Would it be possible to prepare **nitrogen azide**?



This molecule, formally N_{10} , if it was sufficiently stable to be isolated in ponderable quantities, would effectively be a second nitrogen **allotrope**. To be frank, I think it would be so unstable as to spontaneously decompose to five very stable N_2 molecules, especially at room temperature. In any case, an attempt to prepare it might be made by either of the two following suggested routes, using the azide chemistry outlined earlier:



The nitrogen trichloride suggested as the substrate is a very unpleasant, **potentially hazardous, explosive compound**. It appears to be stable at room temperature, but is known to detonate at around 93°C . It has been described as “..... a yellow, thick, oily liquid, with a pungent odor, evaporates readily in air, very unstable, decomposes in light” [from the Merck Index, 8th ed., P.G. Stecher et al. (eds.), Merck & Co., Rahway, NJ, 1968; pp. 738-739]. See also the reference,

- W.A. Noyes, “Nitrogen Trichloride”, Inorganic Syntheses, vol. 1, pp. 65-67, H.S. Booth et al. (eds.), McGraw-Hill, New York, 1939. (see also Note 2, pages 14-15).

The preparative technique of **phase transfer catalysis** is recommended as a possible method of synthesis of the new nitrogen compound. The nitrogen

trichloride is insoluble in water, but slowly hydrolyses when exposed to it. However, NCl_3 is readily soluble in organic solvents such as benzene and chloroform. In phase transfer catalysis (PTC), an organic-soluble quaternary salt, eg. tetra-n-butylammonium chloride, is dissolved in the water phase of the two-phase system, together with the nucleophilic reagent (in this case, azide anion in the form of sodium azide, which is very water-soluble). The NCl_3 is dissolved in the immiscible organic phase, such as chloroform. The two solvents are stirred vigorously together, with the quat “carrying” the azide into the chloroform layer as (in this case), $(\text{n-Bu})_4\text{N}^+ \text{N}_3^-$. We hope that the azide anion will be sufficiently nucleophilic to displace the chlorines from the NCl_3 molecules, to give the desired $\text{N}(\text{N}_3)_3$, which remains in the organic phase. The by-product NaCl is insoluble in chloroform, and remains in the water phase.

Upon conclusion of the reaction, the chloroform layer is removed in a separatory funnel, and is dried (MgSO_4). Then what? Perhaps the chloroform solution could be subjected to GLC/MS analysis, to see if the nitrogen compound has indeed been formed. Obviously, I can't predict the properties of such a unique new material, and how to handle and process it. It's easy to predict the thermal instability of N_{10} , though!

Route 2: bromine azide is reacted with lithium nitride:



Bromine azide, BrN_3 , is a known – if rather unstable – compound, one of the “pseudohalogens”. It has been described (in the Handbook of Chemistry and Physics) as “crystals, or red liquid”, m.p. ca. 45°C , explodes when heated. Another vile reactant! It has been used as a reagent in organic syntheses, adding to olefin bonds as the halogen elements do:

- A. Hassner and F. Boerwinkle, “Ionic and Free-Radical Addition of Bromine Azide to Olefins”, J. Amer. Chem. Soc. **90** (1), pp. 216-218 (1968).

Hassner and Boerwinkle describe their simple preparation of bromine azide :

“For example , 8.0 g of bromine is added to an ice-cooled and stirred mixture of 32.5 g sodium azide , 100 ml of either methylene chloride or pentane , and 25 ml of 30% HCl . The mixture is stirred from 30 min. to 1 hr. and the organic layer containing the bromine azide is decanted and used as is . We use an excess of hydrazoic acid to decrease the amount of dibromo adduct . Using our experimental procedures we have had no explosions” . (p. 216)

I assume lithium nitride rapidly hydrolyses to LiOH and NH₃ (magnesium nitride does so) ; the PTC technique would therefore not be applicable in this case . The chloroform solution of bromine azide would be dried (MgSO₄) , then the appropriate quantity of Li₃N would be added , with rapid stirring . After certain periods of time , aliquots of reaction solution could be removed from the flask and analyzed (GLC/MS) for N₁₀ content .

An attempt might be made to fractionally distill the filtered reaction solutions in both Routes 1 and 2 . Different chlorinated solvents , with varying boiling points , could be used as reaction solvents , then subsequently as “chasers” in the distillation , to “push” the N₁₀ up the distillation column . Possible chlorinated solvents for such use include :

Dichloromethane , CH₂Cl₂ , b.p. 40 °C ;
 Chloroform , CHCl₃ , b.p. 61 °C
 Carbon Tetrachloride , CCl₄ , b.p. 77 °C ;
 1,2-Dichloroethane , ClCH₂CH₂Cl , b.p. 83 °C ;
 Chlorobenzene , PhCl , b.p. 132 °C ; and ,
 o-Dichlorobenzene , PhCl₂ , b.p. 179 °C .

It is interesting to speculate that , if N₁₀ was a flat molecule with a trigonal planar (sp²) central nitrogen atom , its lone pair in the 2p_z native atomic orbital might be able to electronically interact with the azide pi electrons . Such resonance in the molecule would help to stabilize it somewhat . The compound would be deeply colored by the resonance , but it would still be difficult to predict the boiling point for such a unique new material . Since

there are no protons present in it , there would be no hydrogen bonding , but there would be significant van der Waals dipolar bonding between the molecules , mostly from the partial charges on the azide nitrogens . I'm making a semi-educated guess here , and suggesting a boiling point for N₁₀ no higher than 20 °C ; that is , around ambient temperature . Even that guess is dependent on resonance stabilization of the molecule .

If it proved possible to actually distil a small sample of N₁₀ , the distillate should also be subjected to GLC/MS analysis , to ensure the purity of the product (since it might have co-distilled with the chlorinated solvent as an azeotrope) .

The preparation of nitrogen azide , N(N₃)₃ , would certainly be a most interesting project , and needless to say , a rather challenging one , but potentially highly rewarding if crowned with success , as is all chemistry research .

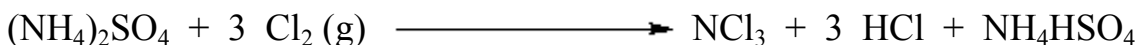
Note 1 : The preparation of N-bromosuccinimide is described in : B.S. Furniss et al. (eds.) , Vogel's Textbook of Practical Organic Chemistry , 4th ed. , Longman , London , 1978 ; p. 284 . Aqueous sodium hydroxide and bromine (in carbon tetrachloride) are used as the N-brominating agents of the succinimide substrate . A similar preparation of N-bromosuccinimide , somewhat more detailed , can be found in the corresponding 3rd ed. , 1956 , pp. 926-927 .

The preparation of N-chloropyrrolidinone , alluded to on page 4 above , is mentioned in the following two references :

W.E. Wallis , "N-chloro- or N-bromo-2-oxazolidinones" , Chem. Abs. 75 , 88620j (1971) ; and ,

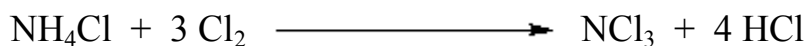
W.E. Wallis , "N-Halo-3-morpholinone" , Chem. Abs. 82 , 125410h (1975) .

Note 2 : The chemical reaction described by Noyes in the Inorganic Syntheses preparation of NCl₃ is :



The reaction was conducted at around 10 °C in a mixture of water and carbon tetrachloride . The product was an approximately 12% solution of pure NCl₃ in CCl₄ , which is reasonably stable and safe to handle .

“Nitrogen trichloride is formed almost quantitatively by the action of excess chlorine or hypochlorous acid with ammonium ion in acid solution :



The reaction can be carried out in chloroform to give solutions which are stable for several days . The handling of dilute solutions containing less than 18% NCl₃ is not dangerous , but above this concentration it is an exceedingly explosive substance ”.

- K. Jones , “Nitrogen” , pp. 147-388 in Comprehensive Inorganic Chemistry , vol. 2 , A.F. Trotman-Dickenson et al. (eds.) , Pergamon Press , Oxford , UK , 1973 ; from p. 295 .

Nitrogen trichloride is – or has been , in the past – used on a large scale , in the form of a very dilute gaseous solution in air , in the bleaching and sterilizing of flour .

I recently discovered that German researchers tried to synthesize N-azidoamines back in the early 1960s , and found them to be extremely unstable , explosive compounds :

H. Bock and K.L. Kompa , “Dimethylamine Azide” , Chem. Abs. 57 , 10992h (1962) ; Angew. Chem. 74 , p. 327 (1962) ; Angew. Chem. Internat. Ed. Engl. 1 (5) , p. 264 (1962) .

“Me₂NCl was stirred several days with NaN₃ in an inert solvent to give 25% 1,1-dimethyltetrazine , b.p. 32 °C (11 mm) , explosive , strong bands at 2110 and 1210 cm⁻¹ ”.

H. Bock and K.L. Kompa , “N-Haloamines . III . Nucleophilic Substitutions in N-Chloroamines” , Chem. Abs. 62 , 6353c (1965) ; Z. Anorg. Allgem. Chem. 332 (5-6) , pp. 238-246 (1964) .

In this latter paper Bock and Kompa comment (note 21 , p. 243) ,

“Es sei an dieser Stelle darauf hingewiesen , dass die ausgeblasenen Loesungen mit ausserordentlicher Heftigkeit zu explodieren vermoegen schwere Handverletzung unter Verlust zweier Finger des einen (K.-L. K.) von uns”.

The website Babelfish (<http://babelfish.altavista.com/>) provided a machine translation of this statement for me , as follows :

“It is pointed out here that the blown out solutions with extraordinary violentness are able to explode heavy hand injury under loss of two fingers one (K.-L. K.) from us”.

It seems that Professor Bock’s research assistant or grad student , Kompa , was badly injured in the explosion of the N-azidodimethylamine . Clearly , the N-azidoamines (and likely the amides , too) , formally known as tetrazines , are too dangerous for chemists to handle safely , so I must implore all the readers of this ebook **NEVER** to actually do any of the experiments I discuss here ! I hope you enjoy the chemistry in my ebooks and find it stimulating and thought-provoking . I believe most of the chemistry I write about is fairly reasonable and practical , but – as it turns out – **not** in this case of the linear-chain tetrazines . (The heterocyclic tetrazines are generally stable enough to be prepared and manipulated safely) .

I could make one exception , that of the reaction of cyanuric chloride with three equivalents of sodium azide (sketch , [page 9](#) above) . In this case a tetrazine isn’t formed , and the azido groups are attached to carbon atoms ,

not to nitrogens . I have the impression that C-azides are more stable than N-azides . Also , the triazide product may be stabilized to a certain extent by resonance stabilization with the aromatic ring . The only other C–N compounds I know of are cyanogen , NC–CN , and its polymer . The C_3N_{12} molecule I proposed would be interesting to synthesize and study , and as mentioned , it might have useful properties as a commercial explosive , if it could be manufactured and handled safely . By the way , azide anion is a “medium-strength” nucleophile , not as strongly nucleophilic as , say , cyanide or iodide , but more so than oxygen-based or other halide anions :

M.B. Smith and J. March , March’s Advanced Organic Chemistry , Reactions , Mechanisms , and Structure , 6th edition , John Wiley , Hoboken (NJ) , 2007 ; Table 10.8 , "Nucleophilicities of Some Common Reagents" , p. 494 . This Table is also in earlier editions of March’s textbook .

So the reaction I outlined above of cyanuric chloride with NaN_3 might actually be feasible . I would suggest the technique of **phase transfer catalysis** as the method of choice for the synthesis of cyanuric azide . For reviews of phase transfer catalysis , see :

E.V. Dehmlow , “Phase Transfer Catalysis” , Chemtech , pp. 210-218 (April 1975) ; this is essentially the same article as : *ibid.* , “Phase-Transfer Catalyzed Two-Phase Reactions in Preparative Organic Chemistry” , Angew. Chem. Internat. Ed. Engl. **13** (3) , pp. 170-179 (1974) .

R.A. Jones , “Applications of Phase-Transfer Catalysis in Organic Synthesis” , Aldrichimica Acta **9** (3) , pp. 35-45 (1976) . This article can be downloaded from the Web (PDF document , 3317 KB) from the Aldrich website , for free , at http://www.sigmaaldrich.com/aldrich/acta/al_acta_09_03.pdf .

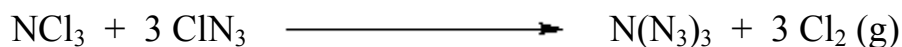
K. Sjöberg , “PTC in Practice” , Aldrichimica Acta **13** (3) , pp. 55-58 (1980) . This article can be downloaded from the Web (PDF document , 2990 KB) from the Aldrich website , for free , at http://www.sigmaaldrich.com/aldrich/acta/al_acta_13_03.pdf .

M. Makosza and A. Jonczyk , “Phase-Transfer Alkylation of Nitriles : 2-Phenylbutyronitrile” , Org. Synth. Coll. Vol. 6 , p. 897-900 (1988) . This is an excellent example of an experimental procedure based on phase transfer catalysis . It can be downloaded from the Web (PDF document , 183 KB) for free , from the Organic Syntheses website at <http://www.orgsyn.org/orgsyn/pdfs/CV6P0897.pdf> .

The nitrite anion , on the other hand , is only a rather feeble nucleophile , and so probably wouldn't react with the cyanuric chloride to provide the hypothetical trinitro adduct . There is also the possibility of it reacting , but yielding the **trinitrite** compound . This situation is known in the case of silver nitrite reacting with alkyl halides , to give a mixture of the corresponding nitroalkane and alkyl nitrite .

Bock and Kompa also investigated the reaction of nitrogen trichloride with sodium azide , as reported in their “N-Haloamines” paper cited above on [page 16](#) . Thus , they anticipated my proposal for the possible preparation of the nitrogen allotrope , nitrogen azide , $N(N_3)_3$, or N_{10} , by forty years ! NCl_3 (solution in CH_2Cl_2) and NaN_3 (suspension in DME) reacted at - 70 to - 50 °C , but yielded only the theoretical amounts of nitrogen gas and sodium chloride residue . No reaction occurred below - 80 °C . Nitrogen azide is indeed too unstable to be isolated in significant quantities , even at very low temperatures . So that idea must be abandoned .

For the record , I came across another reference to nitrogen triazide, N_{10} : L.A. Pilato , J. McGrath , and W.T. Reichie , in the “Heart Cut” feature of Chemtech , April , 1975 , p. 196 . They speculated that it might be prepared by the reaction :



Their prediction , and that concerning a related covalent azide , $C(N_3)_4$, was based on the uranium azide chemistry reported in a research paper by German chemists that they had abstracted in their monthly column .

There may be another safer , more practical route to the carbon synthons discussed above . The **N-nitroso derivatives** of secondary amines and amides can be readily prepared , usually from the hydrochloride salt dissolved in water , with the addition of an equivalent amount of sodium nitrite , the two solutions being chilled in an ice bath from 0 – 5 °C to protect the nitrous acid so produced from decomposition . Many N-nitroso derivatives of secondary amines and amides have been prepared in the past ; in fact , such derivatives have been used in the identification of unknown nitrogen compounds :

R.L. Shriner et al. , The Systematic Identification of Organic Compounds , 7 th edition , John Wiley , New York , 1998 ; p. 245 .

There are several preparations of N-nitroso compounds described in Organic Syntheses , which , as pointed out above , can be downloaded for free from the Web :

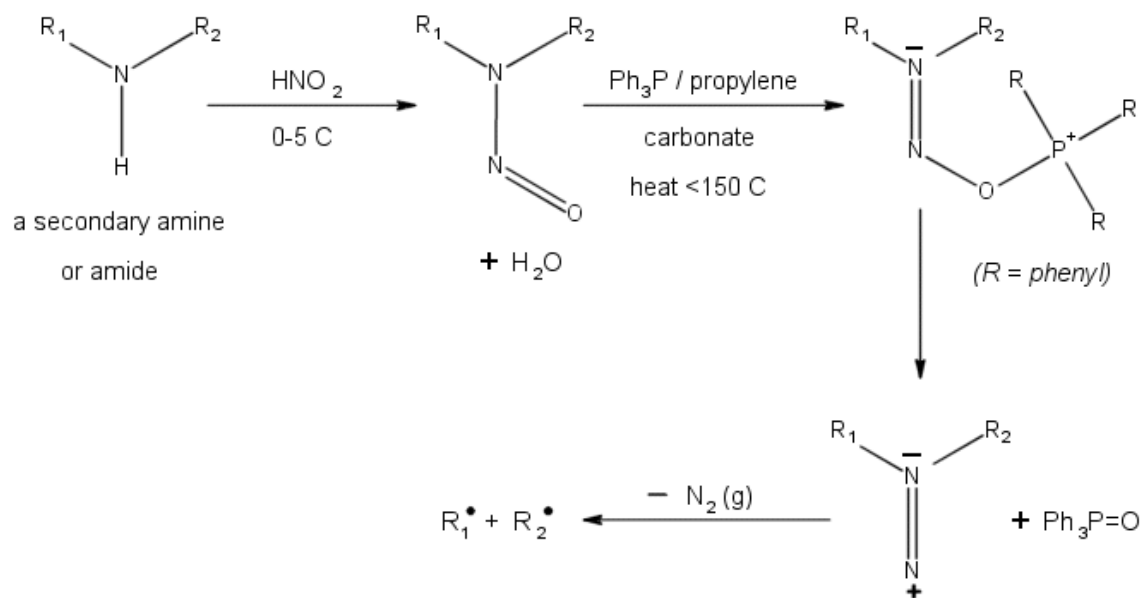
Th. J. de Boer and H.J. Backer , “p-Toluenesulfonylmethylnitrosamide” , Org. Synth. Coll. Vol. 4 , pp. 943-946 (1963) ; PDF document (148 KB) , at <http://www.orgsyn.org/orgsyn/pdfs/CV4P0943.pdf> .

F. Arndt , “Nitrosomethylurea” , Org. Synth. Coll. Vol. 2 , pp. 461-463 (1943) ; PDF document (181 KB) at <http://www.orgsyn.org/orgsyn/pdfs/CV2P0461.pdf> .

W.W. Hartman and L.J. Roll , “N-Nitrosomethylaniline” , Org. Synth. Coll. Vol. 2 , p. 460 (1943) ; PDF document (116 KB) , at <http://www.orgsyn.org/orgsyn/pdfs/CV2P0460.pdf> .

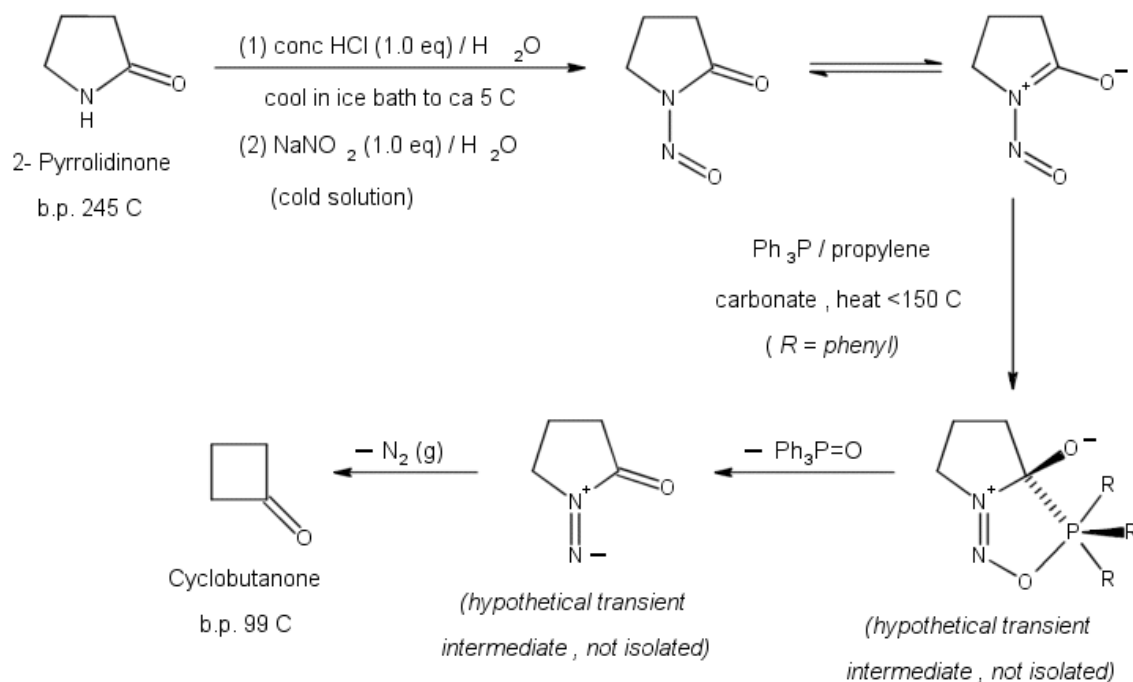
The reagent **triphenylphosphine** is well known for its ability to bond to , and extract oxygen atoms from molecules . The Wittig reaction , for example , takes advantage of the very strong phosphorus-oxygen bond in its synthesis of olefins from the combination of aldehydes and ketones with the alkylidene ylid of triphenylphosphine . It’s possible that triphenylphosphine will bond to the oxygen atom of the N-nitroso group , thus effectively deoxygenating the compound . The intermediate expels a nitrogen molecule to provide the synthon fragments intended for the formation of new

carbon-carbon bonds . Here's a general reaction scheme for this proposed new synthetic route :



A ring closure variation of this N-nitroso / triphenylphosphine reaction might take a similar course , with extraction of the nitroso oxygen and expulsion of the nitrogen molecule from an unstable intermediate . A cyclic intermediate is proposed in a first step , from which triphenylphosphine oxide separates (and might be recovered later by crystallization from the reaction mother liquors) . The reaction scheme to prepare cyclobutanone from 2-pyrrolidinone is outlined on the next page . Note that the closing of linear chains into four-carbon rings is usually quite difficult , so this course of the reaction to distil off cyclobutanone is by no means assured . Nevertheless , it would be an interesting reaction to investigate , as would the general scheme of deoxygenating N-nitrosoamines and amides with triphenylphosphine to provide new carbon synthons for organic synthesis .

Cyclobutanone Synthesis :



I have suggested the use of propylene carbonate as the solvent of choice for these reactions. It has a remarkably high dielectric constant (65-69) and dipole moment (4.9 Debyes), superior to almost all other organic solvents; in other words, propylene carbonate (PC) is a very polar solvent. It also has a high boiling point (242 °C), although PC is known to start decomposing (to ethylene oxide and CO₂) above 150 °C:

W.J. Peppel, "Preparation and Properties of the Alkylene Carbonates", Ind. Eng. Chem. **50** (5), pp. 767-770 (1958). Several physical properties of PC tabulated in this review: m.p. - 49.2 °C; b.p. 241.7 °C; s.g. 1.2057; dielectric constant, 69.0. Peppel notes that salts dissolved in PC can catalyze its decomposition at elevated temperatures. For example, ethylene carbonate with 1% dissolved LiCl heated at 175 °C for 2 hours gave an estimated yield of 65% of ethylene oxide.

The reaction scheme sketched above includes several polar intermediates, which would be stabilized to a certain extent in a polar environment.

A highly polar solvent such as PC would therefore be recommended for use in the N-nitroso / triphenylphosphine reaction outlined above . The diimide intermediate is also reminiscent of the hydrazones prepared for the **Wolff-Kishner** reduction of the carbonyl group in aldehydes and ketones to the corresponding methylene function , with expulsion of nitrogen from the intermediate .

The usual safety precautions are applicable here as with the N-azidoamines and amides . Although I expect the N-nitroso reaction to be relatively mild and controllable , the interested researcher should still be very careful in carrying it out and observing all the usual safety procedures mentioned above on [page 8](#) . Additionally , it should be noted that N-nitrosos are skin irritants , and the lower molecular weight compounds are thought to be **carcinogens** as well . They should therefore be given the greatest respect and handled with caution , using the appropriate safety equipment . The N-nitrosoamides intended for this proposed reaction scheme shouldn't be treated with any sort of basic , alkaline solution , as a highly toxic , explosive diazoalkane compound may be liberated . The two N-nitrosoamides mentioned on [page 19](#) in Organic Syntheses procedures are in fact intended as diazomethane precursors .

In a second update I have to revise my statement above , near the bottom of [page 16](#) , concerning cyanuric triazide . This compound actually has been prepared , in fact a long time ago in 1921 :

E. Ott and E. Ohse , Chem. Abs. 15 , pp. 2069-2070 (1921) .

They prepared cyanuric triazide in 95% yield from the reaction of cyanuric chloride and sodium azide in aqueous acetone :

“The crystals are very lustrous , highly refractive , and very voluminous (m.p. 94 °C) [cyanuric triazide explodes when heated] with a violet light and a loud report” . It was considered to be somewhat shock sensitive .

In two modern-day studies cyanuric triazide has been investigated as a potential commercial explosive :

M.-H. V. Huynh et al. , “Polyazide High-Nitrogen Compounds : Hydrazo and Azo-1,3,5-triazine” , Angew. Chem. 116 (37) , pp. 5032-5036 (2004) ;

E. Keßenich et al. , Eur. J. Inorg. Chem. 1998 (12) , pp. 2013-2016 .

In the latter paper the authors advise :

“CAUTION : [cyanuric triazide] is explosive ! The explosive nature increases with greater purity and crystal size . Only PE equipment should be used during the preparation and handling of cyanuric azide , and safety equipment like leather gloves and face shield is recommended” (p. 2015) .

Huynh and co-workers comment :

“..... they [the polyazide compounds] are notorious for their extreme sensitivity to spark , friction , and impact as well as poor thermal stability , so their applications are very limited” (p. 5032) ; and ,

“Cyanuric azide is extremely sensitive to friction and spark , and its impact is a half less than that of PETN [pentaerythritol tetranitrate , a commercial and military explosive]” (p. 5034) .

I conclude that cyanuric triazide is indeed a powerful explosive , but that its highly dangerous nature outweighs any usefulness that it might possess as a practical explosive , and indeed it is surpassed in its explosive qualities by well-known commercial products such as PETN .

The reaction of cyanuric chloride with nitrite anion has also been investigated , again a long time ago :

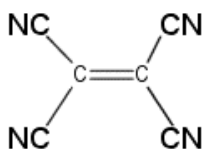
H. Finger , “Derivatives of Tricyanogen” , Chem. Abs. 1 , p. 1548 (1907) .

Finger reported preparing “colourless crystals” and a silver chloride precipitate from the reaction of cyanuric chloride and AgNO_2 in CH_3CN .

However, no mention of any other properties of the product, including any explosive attributes, were made, at least in the Chemical Abstracts article.

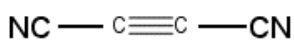
I should also correct my comment on page 17 about cyanogen being one of the few carbon-nitrogen compounds that I knew of. Actually, I knew of (but had a memory lapse at the time) about the two nitriles, tetracyanoethylene (TCNE), a remarkably strong two-electron oxidizer and electrophile, and dicyanoacetylene, a useful intermediate in the Diels-Alder reaction. Finger (cited on the previous page) also prepared tricyanocyanuric acid from cyanuric chloride and cyanide anion; it would be yet another chemical compound with only carbon and nitrogen atoms:

Several Carbon-Nitrogen Compounds



Tetracyanoethylene (TCNE)

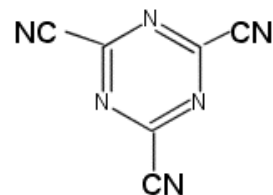
C_6N_4 m.p. 197-199 C



Dicyanoacetylene (*)

(carbon subnitride)

C_4N_2 m.p. 20.5 C b.p. 76.5 C



2,4,6-Tricyanocyanuric acid

C_6N_6

(*) Data from the Wikipedia article at : <http://en.wikipedia.org/wiki/Dicyanoacetylene>