REPORT No. NRO-1-1 (Final)

PERIOD COVERED: 27 September 1990 through 1 March 1993

NOVEL APPROACHES TO THE SYNTHESIS OF FLUORODINITROMETHANE AND FLUORODINITROETHANOL

Contract N00014-90-C-0253
400o048sbi02/30 MAY 1990/1132P

August 1993

A Report on Work Sponsored by the
OFFICE OF NAVAL RESEARCH

July 1993

REPORT No. NRO-1-1 (Final)

NOVEL APPROACHES TO THE SYNTHESIS OF FLUORODINITROMETHANE AND FLUORODINITROETHANOL

by

K. Baum, N. J. Trivedi, J. M. Lovato and V. K. Iyer

A Report on Work Sponsored by the
OFFICE OF NAVAL RESEARCH

Contract N00014-90-C-0253
400o048sbi02/30 MAY 1990/1132P

FLUOROCHEM, INC.

680 South Ayon Avenue
Azusa, California 91702

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NRO-1-1	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Fluorochem, Inc. 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Office of Naval Research
6c. ADDRESS (City, State, and ZIP Code) 680 S. Ayon Avenue Azusa, CA 91702	7b. ADDRESS (City, State, and ZIP Code) 800 N. Quincy Street Arlington, VA 22217-5000
8a. NAME OF FUNDING / SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Contract N00014-90-C-0253
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20301-7100	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 400o048sbi; PROJECT NO. 02/30; TASK NO.; WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Novel Approaches to the Synthesis of Fluorodinitromethane and Fluorodinitroethanol

12. PERSONAL AUTHOR(S)
K. Baum, N.J. Trivedi, J.M. Lovato and V.K. Iyer

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 27SEP90 TO 01MAR93	1993 Aug 27	24

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	
	03		Fluorodinitroethanol

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Fluorodinitroethanol (FDNE) has been produced by nitration of 1,2-dichlorodifluoroethylene to give chlorofluoronitroacetic acid, which was converted to chlorofluoronitronitrosomethane with red fuming nitric acid. Oxidation gave chlorofluorodinitromethane, which was reduced to FDNE with iodide. 1,5-Bis(trifluoroacetyl)3,7-dioxooctahydro-1,5-diazocine was synthesized as an intermediate to 3,3,7,7-tetrakis(difluoraminio)octahydro-1,5-dinitor-1,5-diazocine. Diazocine precursors were prepared by the reaction of epichlorohydrin with t-butylamine and benzylamine.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

CONTENTS

INTRODUCTION

This final report summarizes the work under Contract NOOO14-90-C-0253, a Phase II SBIR contract in continuation of the work on Phase I contract N00014-89-C-0215. The initial objective was to develope a novel low-cost production method for 2-fluoro-2,2-dinitroethanol (FDNE). The potential feasibility of a route based on the nitration of 1,2-dichlorodinitroethylene was demonstrated on the Phase I contract.[1] Subsequently, the program was redirected to the synthesis of cyclic compounds containing both nitro and difluoramino groups.

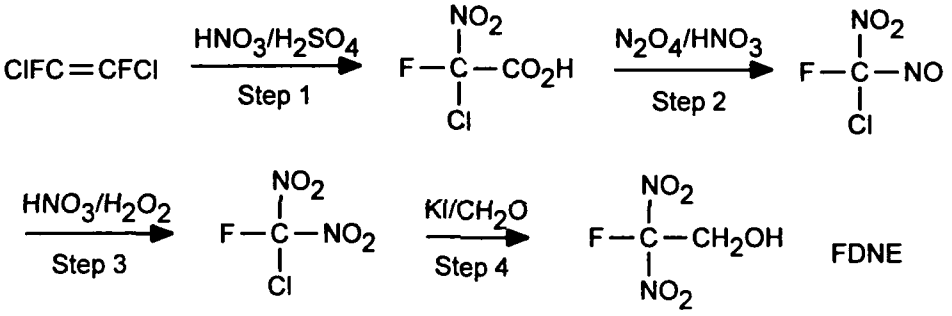
DISCUSSION

Synthesis of 2-Fluoro-2,2-dinitroethanol

Fluorodinitroethanol (FDNE) is a basic building block for energetic plasticizers and binders. Without compromising thermal stability, FDNE provides greater energy content than dinitropropanol, which has been used in large quantities for manufacture of plasticizers. However, the current production cost limits use of FDNE to special applications, and there is a need for a new, low cost production method. Two methods[2] have been used previously for manufacturing fluorodinitroethanol and both have significant difficulties. One was based on the fluorination of nitroform and the other on the fluorination of 2,2-dinitropropanediol (A-diol). Nitroform was available at low cost from Sweden until the supply was curtailed by a plant explosion in the 1970's. Environmental and safety problems still inhibit resumption of the large-scale production of nitroform. In the alternate process, A-diol was deformylated with base and the salt fluorinated. This aqueous fluorination process was complicated by the formation of large amounts of insoluble sodium fluoride, the expense of the A-diol and difficulty in purifying the product. Both of these processes require elemental fluorine, with attendant high plant capital costs. The objective of the present program was to evaluate new

approaches to the industrial synthesis of FDNE based on the nitration of inexpensive fluorocarbons.

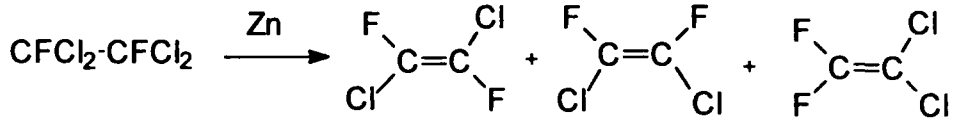
It has been reported in the Russian literature[3] that nitration of 1,2-dichlorodifluoroethylene gives chlorofluoronitroacetic acid, and reaction of the latter with red fuming nitric acid gives chlorofluoronitronitrosomethane. This work was reinvestigated as the basis of an FDNE process. It was expected that oxidation of chlorofluoronitronitrosomethane could give chlorofluorodinitromethane (CFDNM), and that CFDNM could be reduced to give fluorodinitromethane. Fluorodinitromethane is known to react with formaldehyde to give FDNE. These reactions are summarized below.



The starting material for this route, 1,2-dichlorodifluoroethylene, is available commercially in laboratory quantities, but the material was found to be contaminated by about 10% of 1,1-dichlorodifluoroethylene. Because this compound can potentially give a toxic byproduct, 1,1-difluoronitroacetic acid, synthetic routes to the olefin were investigated.

One method that was examined briefly is the pyrolysis of dichlorofluoromethane.[4] This reaction is analogous to the industrial production of tetrafluoroethylene from chlorodifluoromethane. When dichlorofluoromethane was passed through a quartz tube packed with ceramic chips at 750-780 °C, the desired product was obtained, but the yield was low and the material was contaminated with several unidentified compounds. When the experiment was repeated at a lower temperature range, 600-625 °C, similar results were obtained.

The zinc mediated reduction of 1,2-difluorotetrachloroethane[5] was found to be a more practical route to 1,2-dichlorodifluoroethylene. When the reaction was carried out in ethanol, yields of 53-80% of *cis*- and *trans*-1,2-dichlorodifluoroethylene were obtained, but the product contained 10% of the 1,1-dichlorodifluoroethylene isomer, as did the commercial material. Because of the proximity of the boiling points of the product and the solvent, redistillation was required. To avoid this problem, the reduction was carried out in dimethyl sulfoxide. The yield was improved to 86%, and simple distillation sufficed. However, the byproduct, 1,1-dichlorodifluoroethylene was still formed.



The nitration of 1,2-dichlorodifluoroethylene was shown previously[1] to give chlorofluoronitroacetic acid. Additional experiments carried out to improve the yield are shown in Table 1. The nitration agent was a mixture of 100% nitric acid and 30% oleum, and the volatile olefin was refluxed under a dry-ice condenser.

Table 1. Nitration of 1,2-dichlorodifluoroethylene.

entry	NO_3 (mL)	Oleum (mL)	Temp (°C)	Solvent (mL)	Yield (%)
1	6.6	8.8	15	neat	40
2	6.6	8.8	15	neat	26
3	9.0	11.0	0	neat	29
4	9.0	11.0	0	neat	22
5	9.0	11.0	15	CH_2Cl_2 (25)	26
6	6.6	0	0-5	CH_2Cl_2 (150)	12

The low yields were attributed to loss of the starting olefin, even with a dry-ice condenser. One run was then carried out using a stainless steel cylinder. In this case, an uncontrolled exotherm occurred, with separation of the valve.

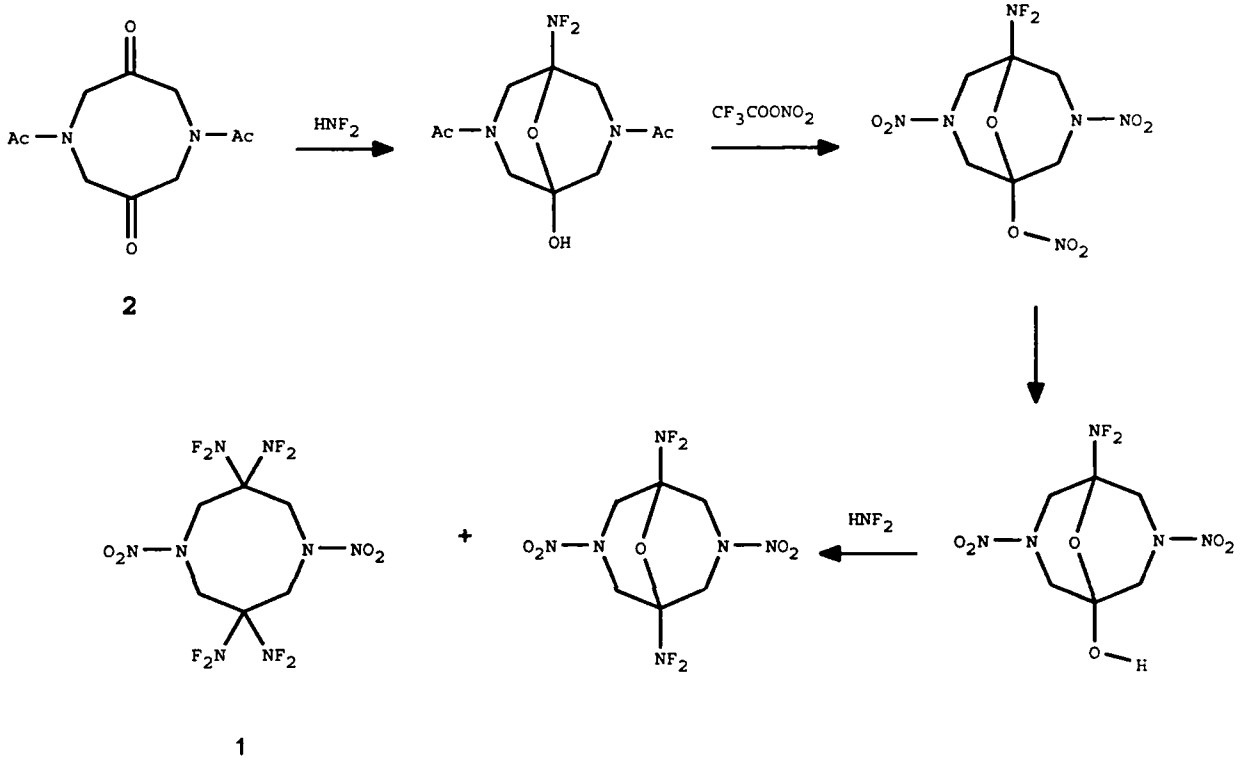
Difluoramino Nitro Compounds

Research at Fluorochem Inc., under contract N00014-88-C-0536 was concerned with the synthesis of new energetic compounds containing both the nitro and the difluoramino groups.[6] There was considerable amount of work done in the 1960's toward synthesizing difluoramino compounds, with some incidental work on mixed nitro-difluoramino compounds. More recent advances in explosives theory concerning the importance of cyclic structures and oxygen balance on performance led to a reinvestigation of this area.

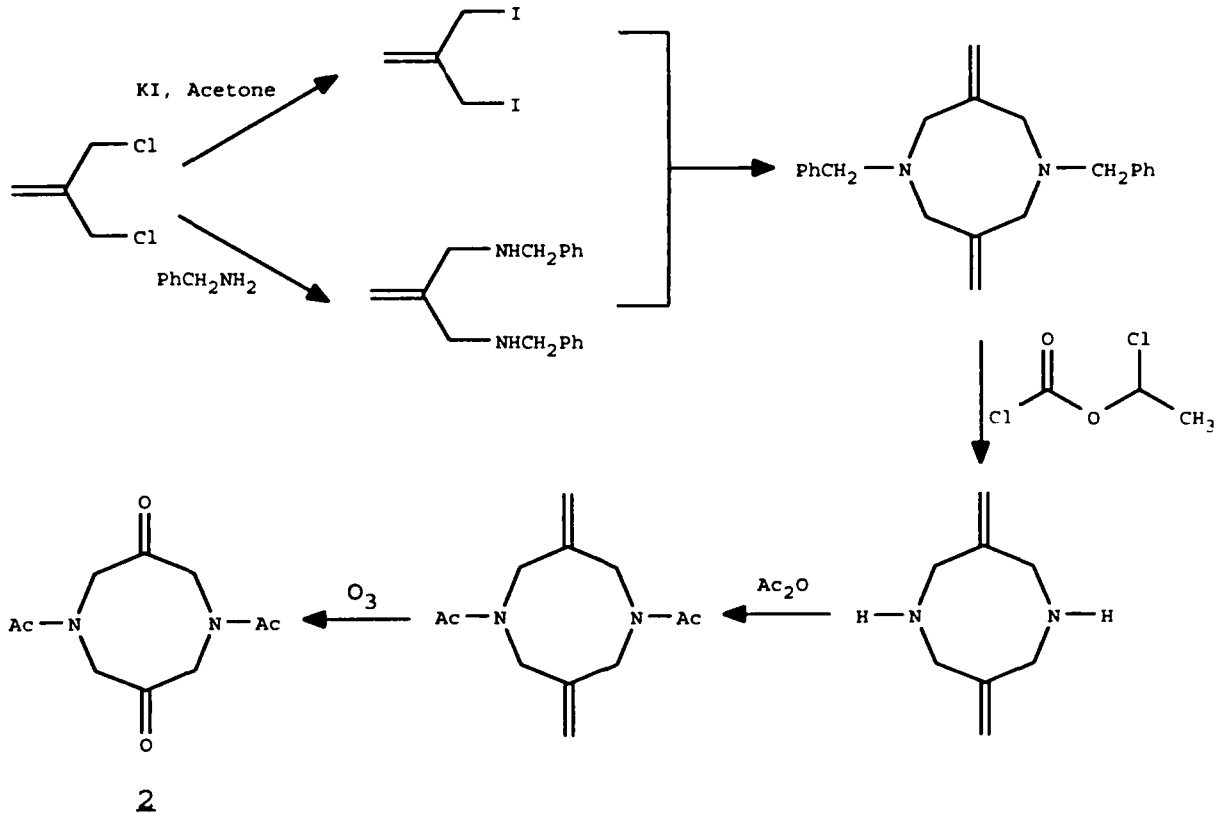
Oxygen balance is an important determinant of performance for explosives. Because oxygen is divalent, nitro groups can consume twice as much fuel in combbustion stoichiometry as difluoramino groups, but difluoramino groups provide greater release of energy. Initially, our approach, therefore, was to select target compounds with sufficient nitro groups for complete combustion of the hydrocarbon backbone to CO and water. Subsequent calculations by researchers at the University of Maryland[7], the Naval Surface Weapons Center[8] and the Naval Ordanance Station[9] indicated that the energy advantage of the difluoramino group is of greater importance than the oxygen contribution of the nitro group, and optimum performance can be obtained for compounds with less than CO oxygen balance.

Consequently, the major effort of the research program was placed on the synthesis of the 8-membered ring compound, 3,3,7,7-tetrakis(difluoramino)octahydro-1,5-dinitro-1,5-diazocine (1). This diazocine was prepared by the difluoramination and nitration of 1,5-diacetyl-3,7-dioxo-octahydro-1,5-diazocine (2)in low yields. Ketones are converted to bis(difluoramino) compounds by reaction with difluoramine in sulfuric acid[10]; difluoramine is

prepared by the hydrolysis of difluorourea, which is obtained by the direct fluorination of urea.[11]



The diketone precursor was prepared by a multi-step synthesis outlined below..



2

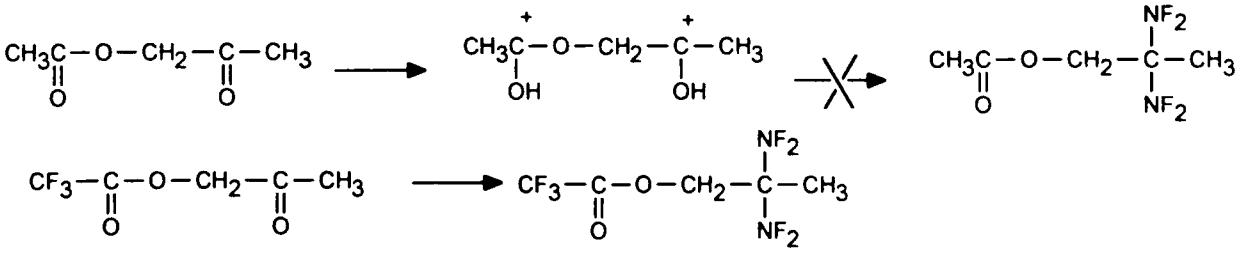
Commercialy available 3-chloro-2-(chloromethyl)propene was reacted with benzylamine to obtain 1,3-dibenzylamino-2-(methylene)propane. Also, 3-chloro-2-(chloromethyl)propene was reacted with potassium iodide in acetone solvent to prepare the corresponding diiodo compound. Coupling of the diamine with the diiodo compound gave 1,5-dibenzyl-3,7-dimethyleneoctahydro-1,5-diazocine. Debenzylation and subsequent acetylation of the diazocine gave the acetylated intermediate, 1,5-diacetyl-3,7-dimethyleneoctahydro-1,5-diazocine. Ozonolysis of the olefinic functionalities then gave the NN'diacetyl diketone (**2**).

The difluoramination of the diketone derivative (**2**) is complicated by the tendency of this structure to form transannular bridges. Nitration of the resulting hemiacetal resulted in the formation of the dinitramino hemiacetal with a bridgehead difluoramino group. Difluoramination under sufficiently strong conditions to cleave the transannular ether bond

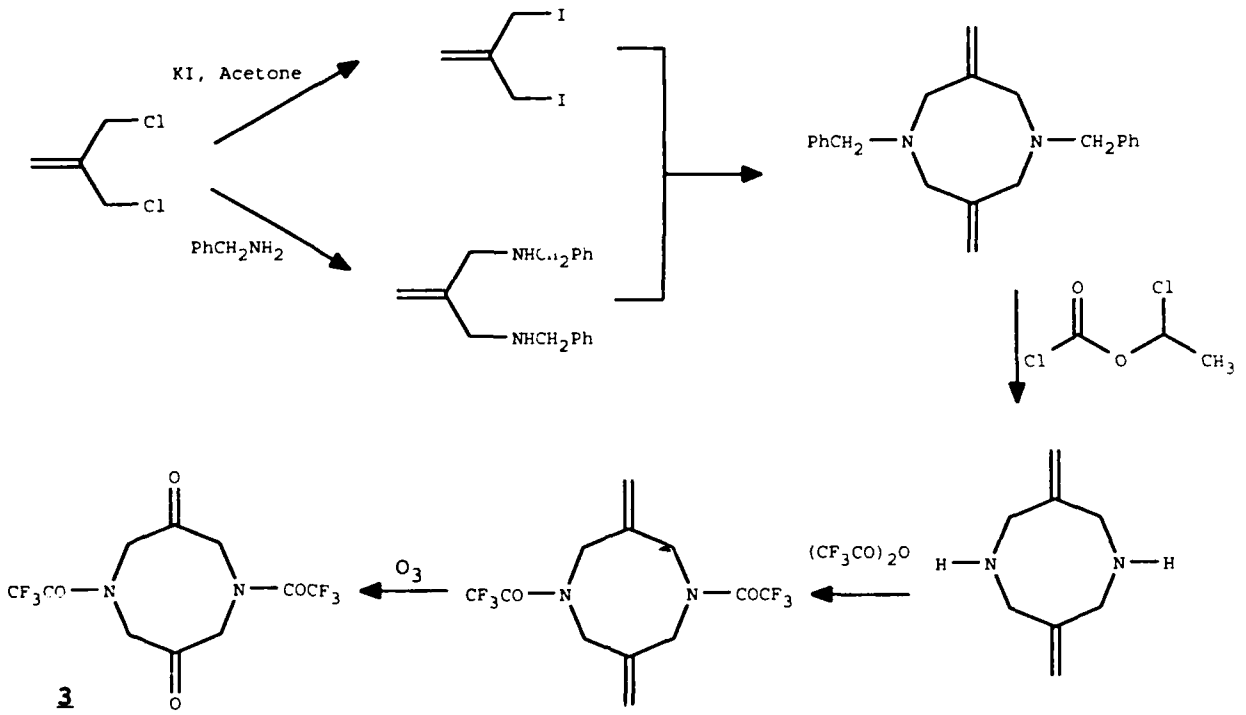
gave the target compound, 1,5-dinitro-3,3,7,7-tetrakis(difluoramino)octahydro-1,5-diazocine (**1**) in low yield. Nitramines are unstable under these strongly acidic conditions, resulting in destruction of the product under the conditions of its formation.

The goals of the present research program were twofold. A diazocine derivative is needed with a blocking group on nitrogen that can withstand difluoramination conditions. This blocking group would then be replaced with nitro groups to give the target compound, 1,5-dinitro-3,3,7,7-tetra(difluoramino)octahydro-1,5-diazocine (**1**). A second objective of the work was to develop a route to the basic ring system that is suitable for larger scale implementation. Problems with the present method include the use of expensive reagents not available on a large scale, environmental problems and the large number of reaction steps.

The initial approach was to synthesize a precursor diketone diazocine with more acid-stable substituents on the nitrogen atoms. The diacetyl derivative, (**2**), failed to give bis(difluoramine) derivatives of the ketone. Because the formation of bis difluoramines proceeds through α-difluoramino carbonium ions, the presence of another center in the molecule that is protonated in concentrated sulfuric acid inhibits the difluoramination. The degree of electron-withdrawing effect of substituents can be critical. For example, although acetoxyacetone does not undergo difluoramination, (trifluoroacetoxy)acetone does.



The trifluoroacetyl analog of the diketone diazocine (**2**), 1,5-diacetyl-3,7-dioxo-octahydro-1,5-diazocine was therefore prepared. The synthetic route was similar to that used for the acetyl derivative.

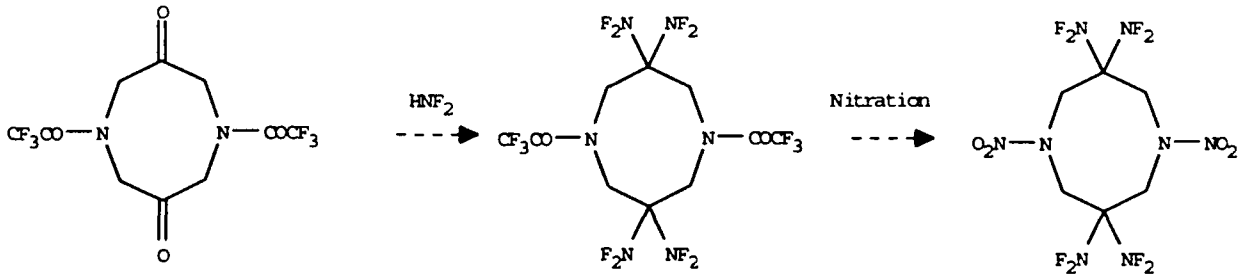


3

Thus, 3-chloro-2-chloromethylpropene was reacted with potassium iodide in refluxing acetone to obtain the corresponding diiodo compound in 85-89% yield. In a separate reaction the above dichloro propene was reacted with excess benzylamine to obtain N,N'-dibenzyl-2-methylene-1,3-propanediamine in 95% yield. The coupling of the diiodide with the diamine was achieved by simultaneous dropwise addition of the ethanolic solutions of the diiodide and the diamine into a flask containing a suspension of potassiun carbonate in ethanol. After the mixture was refluxed for 6 hours, workup gave 1,5-dibenzyl-3,7-dimethyleneoctahydro-1,5-diazocine as a reddish, viscous oily product in 75% yield. This oily product was treated with HCl to obtain the bis(hydrochloride) salt which is convenient to store. A solution of dibenzyl diazocine in 1,2-dichloroethane was treated with α-chloroethyl chloroformate (ACE-Cl) to remove the benzyl groups and the octahydro-3,7-dimethylene-1,5-diazocine dihydrochloride was obtained. Trifluoroacetylation of this diazocine was carried out by reacting the debenzylated diazocine with trifluoroacetic anhydride in THF and 1,5-bis(trifluoroacetyl)-3,7-dimethyleneoctahydro-1,5-diazocine was obtained in 85-90% yield.

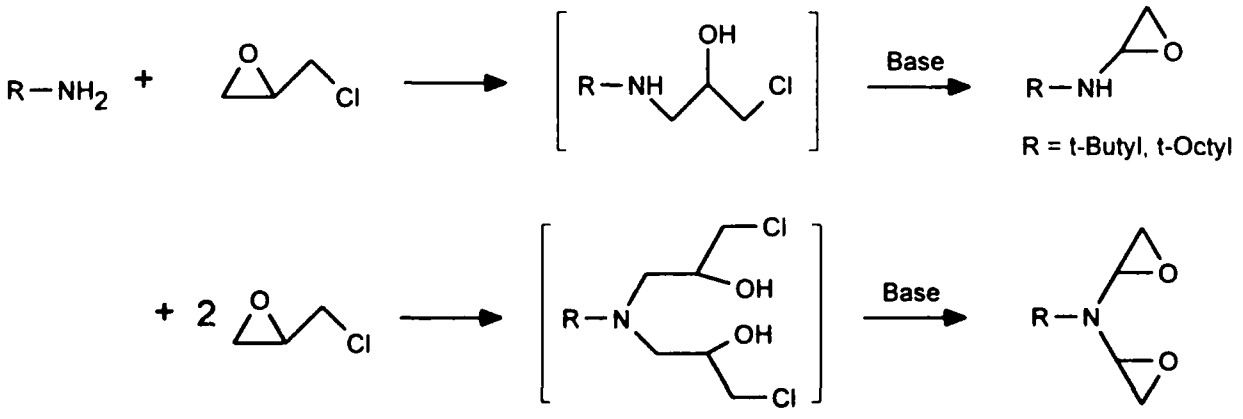
The trifluoroacetylated diazocine was oxidiazed by ozonolysis to yield the desired precursor,1,5-bis(trifluoroacetyl)3,7-dioxo-octahydro-1,5-diazocine (3).

The trifluoroacetyl groups should be stable to the difluoramination conditions. The deacylative nitration then should give the target compound (1) directly. If the trifluoroacetyl group is resistant to substitution, an additional hydrolysis step can be used.



3 1

To obtain a more direct pathway to diazocine intermediates, reactions of amines with epichlorohydrin were examined. Gaertner[12] reported that the condensation of tertiary alkyl amines with one or two equivalents of epichlorohydrin gives 1-*t*-alkylamino-3-chloro-2-propanols, and subsequent dehydrohalogenation gives the correspoding N-*t*-alkylglycidylamine or the N-*t*-alkyldiglycidylamines.



The reactions of benzylamine and *t*-butylamine of with epichlorohydrin were reexamined in the present work. The condensation of benzylamine with excess epichlorohydrin in hexanes at room temperature was followed by GC and NMR analyses. The reaction mixture showed N-benzyl(2-hydroxy-3-chloropropyl)amine (the mono adduct) and N-benzyldi(2-hydroxy-3-chloropropyl)amine (the di adduct) in varying ratio depending on the reaction time. However, even after 72 hours, the reaction did not go completely to the di adduct. When the reaction was carried out in refluxing hexanes for 24 hours, analysis by NMR again showed a mixture of mono and di adduct as well as higher oligomers. More polar solvents such as, acetonitrile, methylene chloride and methanol were also tried with similar results. The neat reaction of benzylamine with 2.1 equivalent epichlorohydrin resulted in exothermic decomposition in 30 minutes.

Efforts were turned toward the condensation of *t*-butylamine and epichlorohydrin. When hexanes, acetonitrile, methylene chloride or methanol were used as solvents, GC and NMR analysis showed N-*t*-butyl(2-hydroxy-3-chloropropyl)amine (the mono adduct) and N-*t*-butyldi(2-hydroxy-3-chloropropyl)amine (the di adduct) in varying ratio depending on the reaction time. However, the neat reaction of butylamine and 2.1 equivalent epichlorohydrin after 7 days gave only the di adduct. The dehydrohalogenation of this reaction product was carried out with sodium hydroxide to obtain N-*t*-butyldiglycidylamine.

Gaertner[11] also reported that the dimerization of N-*t*-butylglycidylamine in methanol at room temperature was extremely slow and after two months, a 15 % yield of cis- and trans-1,5-di-t-butyl-3,7-dihydroxy-octahydro-1,5-diazocine was obtained. The diazocine was prepared in slightly better yield (ca. 28 %) by condensation of N-*t*-butyldiglycidylamine with one equivalent of *t*-butylamine in methanol at room temperature for 33 days.

The reaction of *t*-butyl-N,N-diglycidylamine with an equivalent of *t*-butylamine to obtain the diazocine was examined by modifications of Gaertner's procedure. Higher reaction temperatures as well as new solvent systems were examined with the objective of accelerating

this reaction. Reactions at 50 °C for 15 hours were carried out in methanol, hexanes, and acetonitrile, and the solutions were monitored by GC and NMR. No diazocine was isolated, and only higher oligomers were observed.

A reaction in methanol at room temperature was found to give a 50% yield of 1,5-di-(*t*-butyl)-3,7-dihydroxyoctahydro-1,5-diazocine in 30 days, and after two months, all the starting material was consumed and GC indicated quantitative conversion to the diazocine. Solvent removal and trituration with ether resulted in a 60% isolated yield of the crystalline diazocine.

Attempts to remove *t*-butyl groups from 1,5-di-t-butyl-3,7-dihydroxyoctahydro-1,5-diazocine were made using a method anlogous to that used for debenzylation of 1,5-dibenzyl-3,7-dimethyleneoctahydro-1,5-diazocine.[13] Thus, the di-t-butyl diazocine dissolved in 1,2-dichloroethane was treated with 2-chloroethylchloroformate (ACE-Cl), followed by refluxing the mixture in methanol for 4 hours. However, after workup the starting diazocine was recovered unchanged.'

The de-*t*-butylation of 1-t-butyl-3,3-dinitroazetidine was reported by Hiskey and coworkers,[14] using benzylchloroformate in refluxing chloroform to obtain 1-benzyloxycarbonyl-3,3-dinitroazetidine. The carbamate was cleaved with triflic acid. We applied this method to the di-t-butyl diazocine. The di-t-butyl diazocine was treated with benzyl chloroformate at 0 °C and then the mixture was stirred at room temperature for 3 days. After workup approximately 5-10% yield of yellow oil was obtained. The NMR analysis of this yellow oil in $CDCl_3$ showed the desired 1,5-di(benzyloxycarbonyl)-3,7-dihydroxyoctahydro-1,5-diazocine together with some unreacted di-t-butyl diazocine.

Paudler[15] reported that the condensation reaction of p-toluenesulfonamide and epichlorohydrin under base catalysis gives a 14% yield of 1,5-bis(p-toluenesulfonyl)3,7-dihydroxy-octahydro-1,5-diazocine in 6 hours. In our laboratory, when a mixture of p-toluenesulfonamide, potassium hydroxide and epichlorohydrin was refluxed in a large excess of methanol for 12-15 hours, the desired diazocine was obtained in 28 % crude yield. A

similar reaction using benzamide, however, gave only recovered starting material; the less acidic amide apparently requires a stronger base.

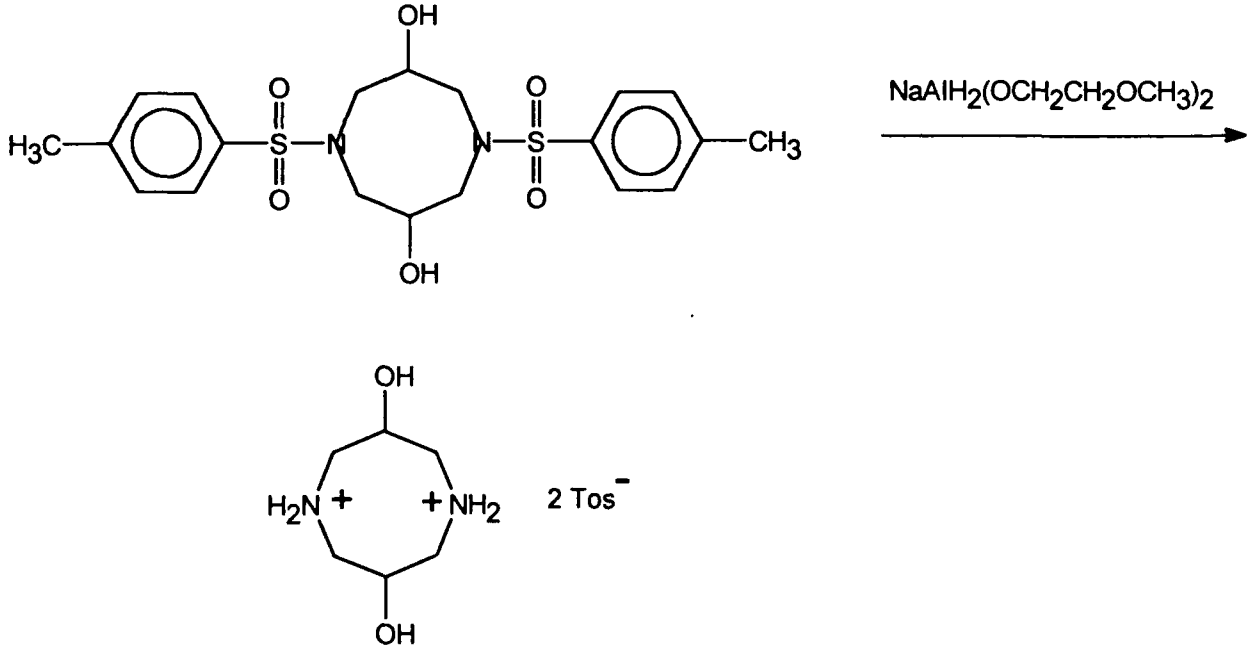
The synthetic transformations required to obtain the desired 1,5-bis(trifluoroacetyl)-3,7-dioxo-octahydro-1,5-diazocine includes the replacement of tosyl groups by trifluoroacetyl groups and the oxidation of the hydroxy groups in 3 and 7 positions to the corresponding diketone. First, the de-tosylation of the diazocine was undertaken.

One of the most frequently used reagents for de-tosylation is hydrobromic acid in acidic organic solvent. For example, the treatment of N-(2,3-dibenzoylpropyl)-p-toluenesulfonanilide with a mixture of hydrobromic acid and acetic acid gave a 90% yield of 2,4-dibromophenyl(2,3-dibenzoxypropyl)amine.[16] Other reports of treatment of sulfonamides with HBr showed the brominated amine to be the major product.[17] Addition of phenol to prevent the bromination of the amines formed has been employed by several workers.[18-21] For systems which are stable to strongly acidic conditions, this method is a good way to obtain the amines from sulfonamides.[22]

For sulfonamides with acid-sensitive side groups, the direct reductive cleavage is a much more difficult transformation. Sulfonamides are stable to catalytic hydrogenation. Hydrogenolysis of p-toluenesulfonazitidide with hydrogen over raney-nickel at 500 psi did not proceed and the starting material was recovered.[23] Sulfonamides are also resistant to lithium aluminum hydride. Primary sulfonamides are not cleaved by this reagent, but secondary sulfonamides have been cleaved using unusually vigorous conditions. Some examples are: N-ethyl-p-toluenesulfonanilide at 120 °C for 4 hours in dibutyl ether, to give a 47% yield of N-ethyl aniline;[24] N,N-diethyl benzenesulfonamide, heated for 7 days in refluxing THF (with sodium aluminum hydride) to give a 57% yield;[25] p-tolunesulfonylazetidine heated for 18 hours in refluxing ether to give only a 10% yield of azetidine.[23] One of the difficulties in carrying out these reactions is attributed to the heterogeneous nature of the reagents.

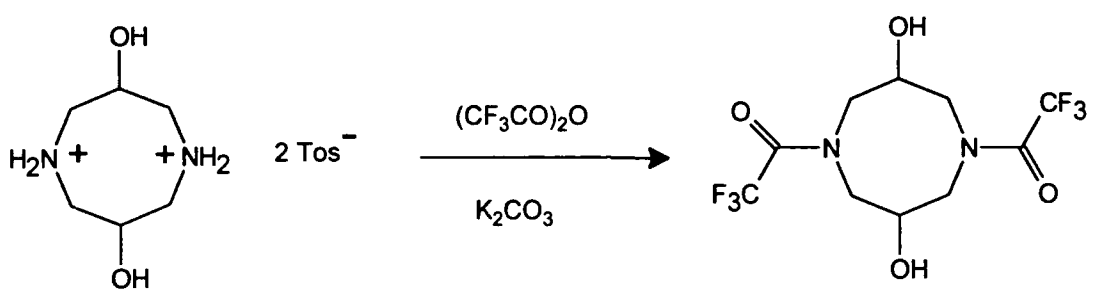
The preparation of sodium bis(2-mehoxyethoxy)aluminum hydride (SMAH), $NaAlH_2(OCH_2CH_2OCH_3)_2$ was reported by Czech workers in the late sixties.[26] This reducing reagent differs significantly from other complex hydrides by its solubility in aromatic hydrocarbons and its increased stability in air. The use of this reagent as a reducing agent for aldehydes, ketones, acids and other functional groups has been reported.[27,28] Reductive cleavage of sulfonamides with SMAH to the corresponding amines in moderate yields were carried out by Gold and Babad[29] in refluxing benzene or toluene.

We carried out the reductive cleavage of the ditosyl diazocine with SMAH in refluxing anhydrous toluene. On the 5 mmol scale, a 40% isolated yield was obtained, and a 50 mmol reaction gave a 47% isolated yield of the detosylated product.



The detosylated diazocine obtained by the above method was reacted with trifluoroacetic anhydride in the presence of potassium carbonate in THF 1,5-bis(trifluoroacetyl)-3,7-dihydroxy-octahydro-1,5-diazocine. Hydroxyl groups are converted to

trifluoroacetate esters under these conditions, but the esters were hydrolyzed during aqueous workup.



The oxidation of this dihydroxy diazocine to the diketone and subsequent difluoramination and nitration steps are being developed on another contract.

EXPERIMENTAL

Proton and carbon NMR spectra were run on a Brücker 200 MHz spectrometer using tetramethylsilane (TMS) as an internal reference. Melting points are uncorrected. Infrared spectra were run on a Perkin-Elmer Model 1605 FTIR spectrometer. Elemental analyses were performed by Galbraith Laboratories, Knoxville, TN.

3-Iodo-2-iodomethylpropene.

To a stirred suspesion of sodium iodide (66.6 g, 0.4 mol) in 325 mL acetone at room temperature was added 3-chloro-2-chloromethylpropene (25.0 g, 0.2 mol) dropwise over a period of 10-15 minutes. The mixture was refluxed for 8 hours and then stirred at room temperature overnight. The mixture was cooled to 0 °C and solids were filtered off. The acetone was removed by rotory evaporation. The residue was dissolved in pentane and then washed with 50 mL aqueous sodium thiosulfate. The organic layer was removed and the aqueous layer was extracted with pentane (2 x 50 mL). The combined organic layers were dried (Na2SO4) and pentane was removed by rotory evaporation to yield 53.4 g (86%) of

crude diiodide. An analytical sample was recrystallized from cold methanol: ^{1}H NMR ($CDCl_3$, TMS) δ 4.12 (s, 4 H), 5.34 (s, 2 H); ^{13}C NMR ($CDCl_3$) δ 6.7, 116.2, 143.8.

N,N'-Dibenzyl-2-methylene-1,3-propanediamine.

To benzylamine (107.2 g, 1.0 mol) initially at 40 °C, was added 3-chloro-2-chloromethylpropene (25.1 g, 0.2 mol) dropwise over a period of 8 hours; the temperature was gradually raised to 68-70 °C over this time. The mixture was then stirred at room temperature overnight and precipitated benzylamine hydrochloride salt was filtered off. After an additional 24 hours, more benzylamine hydrochloride precipitated and was filtered off. The remaining benzylamine then was removed under reduced pressure and any additional benzylamine hydrochloride salt precipitated was filtered off to yield 49.9 g (93%) of N,N'-dibenzyl-2-methylene-1,3-propanediamine as a viscous, reddish oil. ^{1}H NMR ($CDCl_3$, TMS): δ 1.87 (s, 2 H), 3.27 (s, 4 H), 3.72 (s, 4 H), 5.05 (s, 2 H), 7.20-7.29 (broad s, 10 H); ^{13}C NMR ($CDCl_3$): δ 52.1, 52.4, 111.2, 126.0, 127.3, 127.5, 139.8, 145.4.

1,5-Dibenzyl-3,7-dimethyleneoctahydro-1,5-diazocine.

Solutions of 3-iodo-2-iodomethylpropene (40.0 g, 0.150 mol) in 250 mL of absolute ethanol and of *N,N'*-dibenzyl-2-methylene-1,3-propane-diamine (46.0 g, 0.149 mol) in 250 mL of absolute ethanol were added simultaneously dropwise over a period of 2 hours to a suspension of potassium carbonate (45.6 g, 0.330 mol) in 250 mL of absolute ethanol. The slurry was then refluxed for 6 hours and stirred overnight at ambient temperature. Solids were then filtered off and solvent was removed. The residue was then extracted with methylene chloride (400 mL) and inorganic solids were removed. The CH_2Cl_2 solution was then washed with water (2 x 50 mL), dried ($MgSO_4$), and solvent removed under vacuum to give 47.7g (100%) of reddish oil: ^{1}H NMR ($CDCl_3$) δ 3.27 (s, 8 H), 3.65 (s, 4 H), 4.82 (s, 4 H), 7.21-7.38 (m, 10 H); ^{13}C NMR (CD_3OD + $CDCl_3$, 5:1 v/v): δ 59.7, 60.4, 115.0, 127.8, 129.1, 129.9, 140.2, 145.7.

Octahydro-3,7-dimethylene-1,5-diazocine Dihydrochloride.

A solution of 1,5-dibenzyl-3,7-dimethylene-octahydro-1,5-diazocine (44.3 g, 0.139 mol) in 1,2-dichloroethane (100 mL, dried) was stirred under nitrogen and cooled to 0°C. α-Chloroethyl chloroformate (83.5 g, 0.584 mol) was added dropwise over 10 minutes and the mixture was heated at reflux (80°C) for 1.5 hours. Methanol (75 mL) was added and the reaction refluxed at 56-60 °C for 2 h. The mixture was kept in a refrigerator overnight. The solids were then isolated, washed with methylene chloride, and vacuum dried to yield 12.2 g (48%) of octahydro-3,7-dimethylene-1,5-diazocine dihydrochloride. ^{1}H NMR (CD_3OD) δ 4.00 (s, 2 H), 4.87 (s, 2 H), 5.85 (s, 4 H); ^{13}C NMR (CD_3OD) δ 51.9, 132.6, 134.9.

1,5-Bis(trifluoroacetyl)octahydro-3,7-dimethylene)-1,5-diazocine.

Methanol (1.6 mL) was added to a suspension of octahydro-3,7-dimethylene-1,5-diazocine dihydrochloride (5.9 g, 0.03 mol) and K_2CO_3 (37.5g, 0.271 mol) in THF (110 mL, dried) and the mixture was stirred for 0.5 hour. Trifluoroacetic anhydride (69.9 g, 0.333 mol) was added dropwise over 0.5 hour at 0 °C under N_2 purge. The reaction mixture was then stirred for 1 hour at 0 °C and for three days at ambient temperature. The solvent was removed by rotary evaporation and residual solids were stirred in 100 mL of water and 100 mL of CH_2Cl_2 until all solids were dissolved. The organic layer was dried over magnesium sulfate and solvent removed by rotary evaporation. The product crystallized upon removing the last traces of solvent under high vacuum (yield 8.7 g, 94%): ^{1}H NMR ($CDCl_3$) δ 4.11-4.24 (d, d, syn and anti CH_2-N), 5.32 (s, syn =CH_2), 5.43, 5.48 (s, anti =CH_2); ^{19}F NMR ($CDCl_3$) δ -69.12 (-CF_3).

1,5-Bis(trifluoroacetyl)-3,7-dioxooctahydro-1,5-diazocine (3).

Oxygen was bubbled through a solution of 1,5-bis(trifluoroacetyl)-3,7-dimethyleneoctahydro-1,5-diazocine (4.0 g, 0.12 mol) in $CHCl_3$ at -40 to -30 °C for 10

minutes to purge air and then ozone was then bubbled through the solution for 1 hour. The chloroform solution was then flushed with oxygen again to remove ozone. After the bluish color disappeared, 1 mL of H_2O was added, the cooling bath was removed and the oxygen bubbling continued for 45 min. The mixture stirred overnight and filtered to give 3.7g (91%) of 1,5-bis(trifluoroacetyl)-3,7-dioxooctahydro-1,5-diazocine, a white powder: ^1H NMR (DMSO-D_6) δ 4.36-4.67 (two sets of doublets, syn and anti) ; IR 1732.9cm^{-1}(s), 1705(s), 1426.1 (m), 1322.3 (m), 1204.4 (s), 1159.1 (s), 1132.1 (s), 766.7 (m).

1,5-Bis(p-toluenesulfonyl)-3,7-dihydroxyoctahydro-1,5-diazocine.

Epichlorohydrin (100 g, 1.1 mol) was added with stirring to a solution of p-toluenesulfonamide (171 g, 1.0 mol) and potassium hydroxide (56.0 g, 1.0 mol) in methanol (3.0 L). The solution was refluxed overnight and became neutral to pH paper. The precipitated potassium chloride was filtered and methanol was removed on a rotory evaporator. The resulting oily residue was mixed with 500 ml ether and a white solid product precipitated. The solid was filtered and washed with 300 ml of ether. The combined ether solutions were dried over magnesium sulfate and ether removed by rotory evaporation. The residue was dissolved in a minimum quantity of ethanol and water was added to precipitate more product. A total of 67 g of 1,5-Bis(p-toluenesulfonyl)-3,7-dihydroxyoctahydro-1,5-diazocine was obtained (crude yield 28 %); mp 200-202 °C (lit.198-200 °C): ^1H NMR (DMSO-d_6, TMS) as a mixture of cis and trans isomers δ 2.38 (s, 6 H), 2.67-3.87 (m, 10 H), 5.16-5.30 (broad s, 2 H), 7.42-7.72 (m, 8 H); ^{13}C NMR ($CDCl_3$) for trans isomer: δ 143.1, 135.5, 129.8, 126.6, 69.5, 57.5, 20.8.

Detosylation of 1,5-Bis(p-toluenesulfonyl)-3,7-dihydroxy-octahydro-1,5-diazocine.

A solution of 1,5-bis(p-toluenesulfonyl)-3,7-dihydroxy-octahydro-1,5-diazocine (22.7 g. 0.05 mole) in dry toluene (300 mL) was cooled with an ice-bath and SMAH (136.5 g, 0.5 mol) was added, dropwise, under nitrogen, with stirring over a 30-40 minute period. The mixture

was then refluxed for 20 hours. The excess SMAH was decomposed with water (300 mL), ether (250 mL) was added and the mixture was filtered through a celite pad. The aqueous phase was separated, acidified with HCl and then washed with diethyl ether (5 x 250 ml). To this aqueous solution, p-toluenesulfonic acid (19 g, 0.11 mole) was added and the solution was evaporated to dryness to obtain a white solid. This solid residue was recrystallized from 30 ml water to obtain 11.5 g (47%) of the ditosylate salt of the dihydroxy diazocin, m.p. 272 °C (lit.[29] 279 °C).

1,5-Bis(trifluoroacetyl)-3,7-dihydroxyoctahydro-1,5-diazocine

The ditosylate salt of 3,7-dihydroxy-octahydro-1,5-diazocine (1.0 g, 0.002 mole) was suspended (stirring, nitrogen) in 50 ml THF and potassium carbonate (13.8 g, 0.1 mole) added, followed by the dropwise addition of trifluoroacetic anhydride (4.2 g, 0.02 mole) at 0 °C. The mixture was stirred at room temperature for 3 days and then solvent removed on a rotory evaporator. The residue was dissolved in a mixture of 100 mL of water and 250 mL of methylene chloride. The organic layer was dried over anhydrous magnesium sulfate and the solvent removed to yield 1,5-bis(trifluoroacetyl)-3,7-dihydroxyoctahydro-1,5-diazocine (0.32 g, 45%): ^{1}H NMR (DMSO-d_6) δ 2.65-4.60 (m, 10 H), 5.20-5.40 (s, br, 2 H); ^{19}F NMR (DMSO-d_6) δ 168.3 (CF_3).

***t*-Butyl-N,N-diglycidylamine.**

t-Butylamine (73.1 g, 1.00 mol) was added dropwise to a solution of epichlorohydrin (191.0 g, 2.06 mol) in 100 mL of methanol, and the mixture was stirred at room temperature for 4 days. Solvent was removed (25-50 0°C, 25 mm Hg), and the residue was stirred with 50 mL of DMSO and 200 g of 40% aqueous sodium hydroxide. The organic layer was separated and dried. Distillation gave a forerun (13.6 g) of impure product and 77.1 g (42%) of *t*-butyl-N,N-diglycidylamine: bp 87-88 0°C (1.0 mm); ^{13}C NMR ($CDCl_3$) 52.9, 52.6, 52.4, 45.9, 27.2,

27.0; ^{1}H NMR δ 2.5-3.3 (m, 10 H), 1.1 (s, 9 H). GC: 30 m SE-54 capillary column, 100 °C (hold 2 min), increase 10°C/min to 240°C, hold 30 min, retention time 9.6 min.

1,5-Bis(*t*-butyl)-3,7-dihydroxyoctahydro-1,5-diazocine.

A solution of *t*-butyl-N,N-diglycidylamine (18.5 g, 0.100 mol) and *t*-butylamine (7.3 g, 0.100 mol) in methanol (120 mL) was kept at room temperature with stirring for 30 days. After 30 days, GC analysis indicated a 48% product yield. The methanol was removed with a rotary evaporator and the product distilled to give 3.9 g (15 %) of oil, bp 180-220 (2 mm). Loss of product by decomposition during the distillation was evident. The reaction was repeated on the same scale and the reaction time was extended to 2 months. At the end of this period, GC showed that all the starting material was consumed and the yield was quantitative. The solvent was removed by rotary evaporation and the resulting oily residue was triturated with ether to obtain a white precipitate (15.6 g, 60%): ^{1}H NMR δ 2.5-3.5 (br m, 12 H), 1.0 (s, 18 H); GC: 30 m SE-54 capillary column, 60 °C (hold 2 min), increase 10°C/min to 240°C, rt 15.8 and 15.9 min (cis, trans).

Attempted De-t-butylation of 1,5-Di-t-butyl-3,7-dihydroxy-octahydro-1,5-diazocine.

Benzyl chloroformate (3.0 g, 0.018 moles) was added dropwise via syringe to 1,5-di-*t*-butyl-3,7-dihydroxyoctahydro-1,5-diazocine (1.0 g, 0.004 mol) at 0 °C . The mixture was stirred at room temperature for 3 days. The mixture was quenched with 10 ml water and extracted with methylene chloride (4 x 25 mL). The organic layer was washed with aqueous bicarbonate, dried and solvent was removed by rotory evaporation to obtain a yellow oil. The residue (0.13 g) contained unreacted starting diazocine ^{1}H NMR ($CDCl_3$) δ 7.1 (m, 10 H), 4.3 (ss, 4 H), 3.5-2.0 (m, 10 H).

References

1. Fluorochem, Inc. Report No. ONR-9-1, February, 1990, "Novel Approaches to the Synthesis of Fluorodinitromethane and Fluorodinitroethanol."
2. Kamlet, M.; Adolph, H. G. *J. Org. Chem.*, **1968**, *33*, 3073. Grakauskas, V.; Baum, K. *J. Org. Chem.*, **1968**, *33*, 3080.
3. Martynov, I. V.; Kruglyak, Y. L.; Markarov, S. Pl *Zh Obshch. Khim.* **1963**, *33*, 3384.
4. Makoto, H. *Nippon Kagaku Kaishi*, **1979**, 302. *Chem. Abstr.* **90**, 169024e.
5. Locke, E. G.; Brode, W. R.; Henne, A. L. *J. Am. Chem. Soc.*, **1934**, *56*, 1726.
6. Fluorochem, Inc. Report ONR-7-1, "Research in Energetic Compounds", Contract N00014-88-C-0536, September 1991.
7. Ammon, H. L. (University of Maryland, College Park), Personal Communication.
8. Adolph, H. G., Koppes, W. M. and Lawrence, G. W. (Naval Surface Weapons Center, Silver Spring, Maryland), Personal Communication.
9. Baroody, E. (Naval Ordanance Station, Indian Head, Maryland), Personal Communication.
10. Baum, K. J., *J. Amer. Chem. Soc.*, **1968**, *90*, 7083.
11. Grakauskas, V. and Baum, K., *J. Amer. Chem. Soc.*, **1970**, *92*, 2096.
12. (a) Gaertner, V. R., *Tetrahedron Lett.*, **1964**, 141.
    (b) Gaertner, V. R., *Tetrahedron*, **1967**, *23*, 2123.
13. (a) Olofson, R. A., Martz, J. T., Senet, J. P., Piteau, M. and Malfroot, T., *J. Org. Chem.*, **1984**, *49*, 2081.
    (b) Olofson, R. A. and Abbott, D. E., *J. Org. Chem.*, **1984**, *49*, 2795.
14. Hiskey, M. A., Coburn, M. D., Mitchell, M. A. and Benicewicz, B. C., Personal Communication.
15. Paudler, W. W., Gapski, G. R. and Barton, J. M., *J. Org. Chem.*, **1966**, *31*, 277.
16. Heinz, O. and Haeseler, G., *Ber.*, **1936**, *69*, 2311.

17. Kalmann, D. and Hofbauer, G. *Monatsh. Chem.*, **1953**, *84*, 62.

18. Snyder, H. R. and Geller, H. C., *J. Amer. Chem. Soc.*, **1952**, *74*, 4864.

19. Snyder, H. R. and Heckert, R. E., *J. Amer. Chem. Soc.*, **1952**, *74*, 2006.

20. Weisblat, D. I., Magerlein, B. J. and Myers, D. R., *U.S. Patent* 2,562,222. *Chem. Abstr.*, **1952**, *46*, 3093.

21. Weisblat, D. I., Magerlein, B. J. and Myers, D. R. British Patent 676,037. *Chem. Abstr.*, **1952**, *46*, 9600.

22. Noller, C. R., *"Chemistry of Organic Compounds"*,**1957**, p.472, W. B. Saunders Co. Philadelphia.

23. Kolonowski, R. S., *Ph.D. Dissertation*, Univ. of Michigan, **1959.**

24. Klamann, D., *Monash. Chem.*, **1953**, *84*, 651.

25. Field, L. and Grundwald, F. A., *J. Org. Chem.*, **1951**, *16*, 946.

26. Vit, J., Casansky, B. and Machacek, J., *French Patent* 1,515,582.

27. Bazant, V., Capka, M., Cerney, M., Chvalovsky, V., Kochlloefl, K., Kraus, M. and Malek, J., *Tet. Lett.*, **1968**, *29*, 3303.

28. Malek, J. and Cerney, M., *Synthesis*, **1972**, 217.

29. Gold, E. H. and Babad, E., *J. Org. Chem.*, **1972**, *37*, 2208.