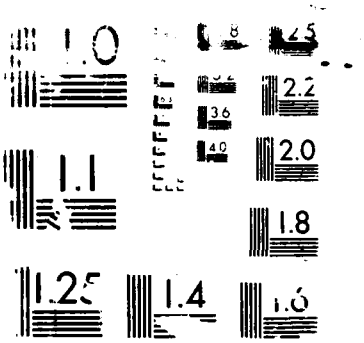
AD-A189 115 SYNTHESIS OF ENERGETIC MATERIALS(U) NAVAL SURFACE WEAPONS CENTER SILVER SPRING MD M CHAYKOVSKY ET AL. MAR 87 1/1

UNCLASSIFIED F/G 7/3 NL


1.0
2.2
2.0
1.1
1.8
1.25
1.4

SYNTHESIS OF ENERGETIC MATERIALS ANNUAL PROGRESS REPORT FOR THE OFFICE OF NAVAL RESEARCH

WORK REQUEST N0001187WX24109

M. CHAYKOVSKY
W. M. KOPPES

MARCH 1987

RESEARCH AND TECHNOLOGY DEPARTMENT

NAVAL SURFACE WARFARE CENTER
Dahlgren, VA 22448 - Silver Spring, MD 20903-5000

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS AD-A189115
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)	5 MONITORING ORGANIZATION REPORT NUMBER(S) Work Request N000187WX24109
6a NAME OF PERFORMING ORGANIZATION Naval Surface Warfare Center	6b OFFICE SYMBOL (If applicable) R11
6c ADDRESS (City, State, and ZIP Code) 10901 New Hampshire Avenue White Oak, Silver Spring, MD 20903-5000	7a NAME OF MONITORING ORGANIZATION 7b ADDRESS (City, State, and ZIP Code)
8a NAME OF FUNDING / SPONSORING ORGANIZATION Office of Naval Research	8b OFFICE SYMBOL (If applicable) Code 432
8c ADDRESS (City, State, and ZIP Code) Arlington, VA 22217	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER 10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
61153N	RR024	02	6R11AA

11 TITLE (Include Security Classification)
Synthesis of Energetic Materials (U)

12 PERSONAL AUTHOR(S)
M. Chaykovsky and W. M. Koppes

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Annual Progress Report	FROM 1/1/86 TO 12/31/86	1987 March 31	

16 SUPPLEMENTARY NOTATION
Reproduction in whole or in part is permitted for any purpose of the United States Government

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

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

The chemistry of the 2,6-diazabicyclooctane ring system was studied toward the synthesis of tetra- and hexa-substituted derivatives. Stable dinitro derivatives were prepared but attempts to prepare tetranitro derivatives by oxidative nitration were unsuccessful, and work on the diazabicyclooctanes was terminated. Methylenedinitramine (MEDINA) was successfully condensed with glyoxal in acetic anhydride to give a substitute dinitroimidazolidine which shows promise as a precursor for the synthesis of bicyclo-HMX.

Trichloroacetamidine condensed with glyoxal and with oxalyl chloride to give a trichloromethyl substituted dihydroxyimidazoline and imidazolinedione respectively. The imidazoline was unstable and could not be converted into the bistrichloromethyl substituted tetraazabicyclooctane ring system by further condensation with trichloroacetamidine. The stable imidazolinedione, ont he other hand, is a potential intermediate for such a condensation reaction. Trihalomethyl-bisformamides and bisacetamides are also potential precursors for this substituted bicyclic ring system. The trihalomethyl groups should stabilize the ring during nitrolysis reactions leading to the bicyclo-HMX system.

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
W.M. Koppes	(202) 394-1182	R11

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

★U.S. Government Printing Office 1986—630-012

CONTENTS

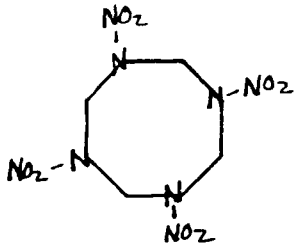
INTRODUCTION

The work described in this report was carried out during 1986 under the sponsorship of the Office of Naval Research, Code 1132P (Dr. R. S. Miller). The effort consisted of two separate tasks: (1) synthesis of energetic monomers and polymers, and (2) synthesis of polycyclic and adamantoid nitramines. Task (1) will be reported on under separate cover by Dr. H. G. Adolph and collaborators. Task (2) is covered in this report. The principal objective of the work is the syntheses of nitramines with high crystal density and energy-density greater than that of HMX.

SYNTHESIS OF POTENTIALLY DENSE NITRAMINES

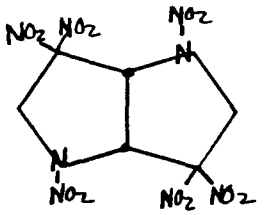
(a) Diazabicyclooctanes.

During the past year, work was continued on the synthesis of the diazabicyclooctanes 2 and 3. These compounds have calculated densities significantly higher than that of HMX (1) and estimated detonation pressures in the range of 420-430 kbar, about 10% greater than that of HMX.



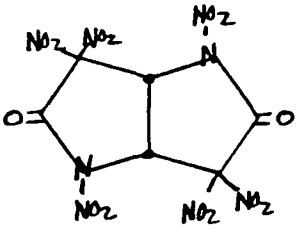
1

P_o calc'd 1.79



2

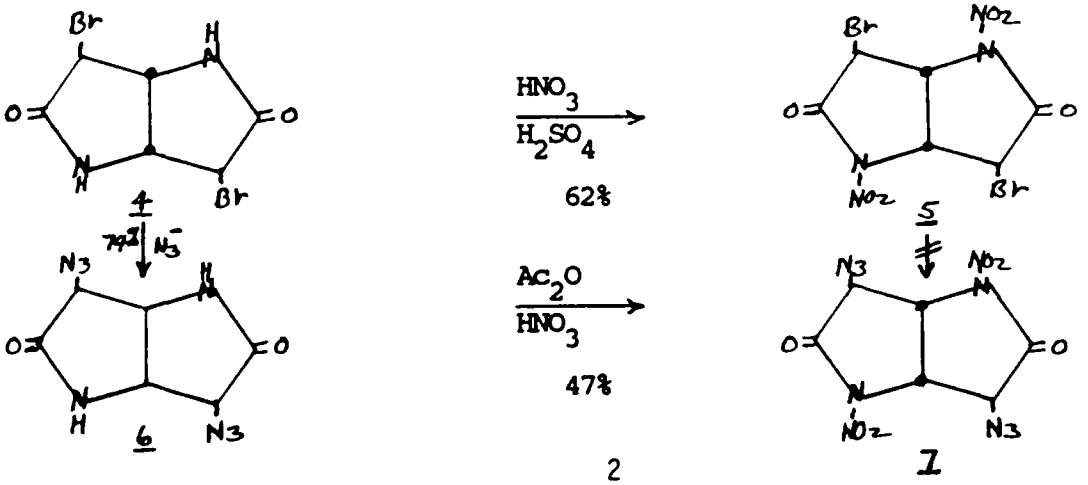
1.88



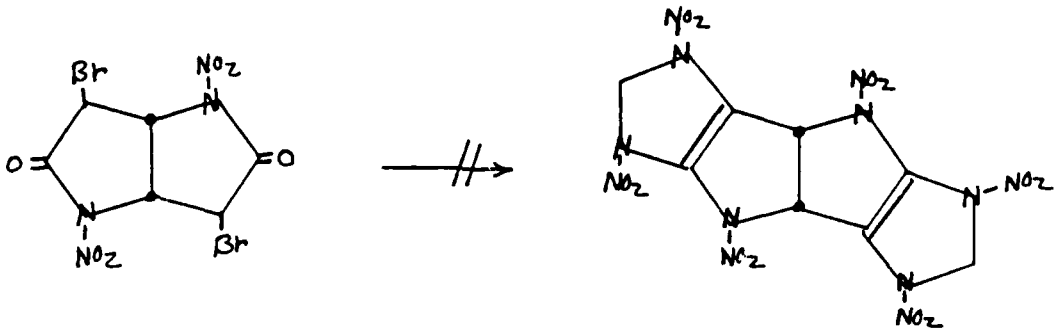
3

2.00 g/cm^3

In our last report[1], we described the synthesis of the bicyclic dibromide (4). Attempts were made to displace the bromines in 4 with nitrite ion in a typical Kornblum reaction[2]. However, the corresponding dinitro compound could not be obtained. Dibromide (4) turned out to be completely inert under various reaction conditions, probably as a result of the exo-nature of the bromines on the cis-fused ring system, which precludes backside attack by nitrite ion. Mixed acid nitration converted the dibromide (4) into the cyclic dinitramide (5). This compound was extremely susceptible to ring-opening reactions upon treatment with nucleophilic reagents. Reaction of 5 with sodium nitrite or lithium azide gave only dark water-soluble products. On the other hand, reaction of lithium azide with 4 gave the diazide (6) in good yield, which could be nitrated to the diazido dinitramide (7).

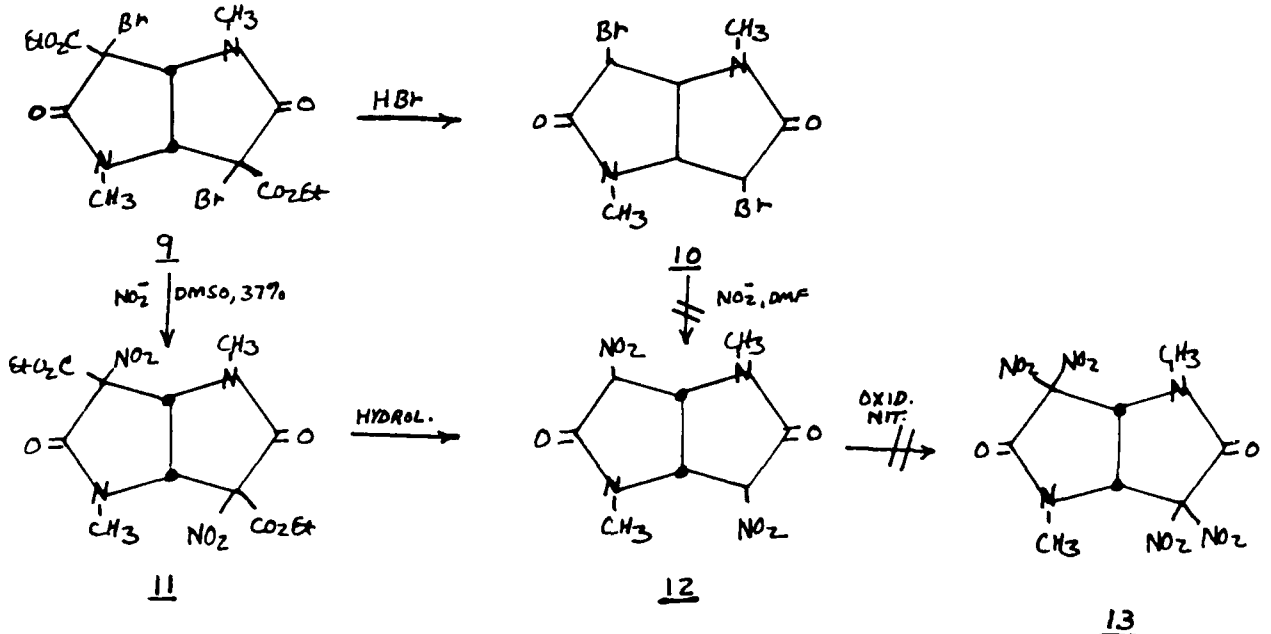


We attempted to utilize compounds 5 and 7 as starting materials for the synthesis of some energetic tetracyclic compounds. For example, reaction of 5 with methylenedinitramine (MEDINA) under suitable reaction conditions might be expected to yield the tetracyclic 8. However, this and other attempted reactions on 5 and 7 were unsuccessful.



5 8

In another approach to the target diazabicyclooctanes 2 and 3, the dibromodiester (9) was prepared by bromination of the parent diester[1]. Hydrolysis gave the dibromide (10). This compound, similarly to 4, was also inert toward nitration under Kornblum conditions. However, the dibromodiester (9) was converted, by nitrite ion in DMSO, into the dinitrodiester (11) in moderate yield[3]. Basic hydrolysis then gave the dinitro bicyclic amide (12). Many attempts were then made to convert 12 into the tetranitro intermediate (13) using various oxidative nitration techniques[4,5]. Since none of these attempts were successful, synthetic work on these diazabicyclooctanes was terminated.

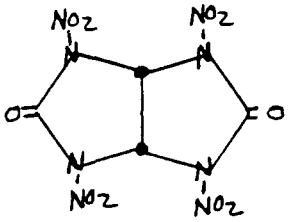


9 10 11 12 13

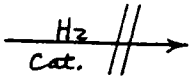
(b) Bicyclo HMX and Derivatives

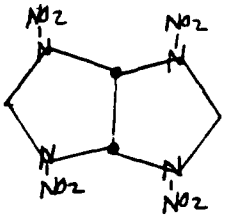
During this period, work was continued on the chemistry of cyclic nitramines with the goal of synthesizing bicyclo-HMX and derivatives. Since tetranitroglycouril (TNGU, 14) is a readily available compound, attempts were made to catalytically hydrogenolyze the carbonyl group under mild conditions of temperature and pressure to obtain bicyclo-HMX (15). Various catalysts such as platinum or palladium on carbon, and Lindlar's catalyst ($Pd-CaCO_3-Pb$) were used. In all cases, complex mixtures of solid amorphous products were obtained from which no single crystalline compound could be separated. The NMR spectra of these mixtures did not show signal peaks which could be expected from bicylo-HMX.

Several years ago[6], we successfully condensed ethylenedinitramine (EDNA) with glyoxal in acetic anhydride to give the cyclic dinitramine (16). The corresponding reaction with methylenedinitramine (MEDINA) proved to be extremely difficult because of polymer formation. However, we now have conditions for the synthesis of the 5-membered cyclic dinitramine (17) in low yield. Following reaction schemes worked out on 16, it should be possible to obtain the dibromide (18), which is a precursor for the synthesis of bicyclo-HMX.

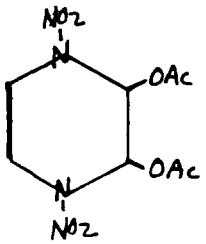


14

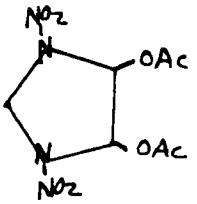




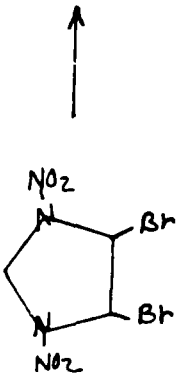
15



16



17



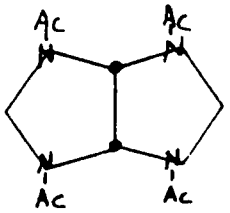
18

In another approach to the bicyclo-HMX structure, the reactions of amidines with glyoxal and oxalyl chloride were investigated. The strategy was to synthesize the tetraazabicyclooctane ring system with groups at the 3,7-positions that would stabilize the ring system toward nitration, as was done successfully in the synthesis of the tetrakis-trifluoromethyl bicyclo-HMX.[1] The amidines, however, would lead to structures with only two pendant trihalomethyl groups on the bicyclo-HMX (Scheme 1). The trichloromethyl groups could potentially be replaced by hydrogen.

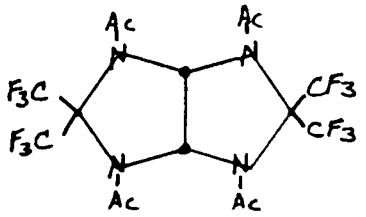
The trichloro- and trifluoroacetamidines were easily prepared by reaction of the corresponding nitriles with ammonia. Attempts to prepare a tetraazabicyclooctane (20) from trichloroacetamidine and aqueous glyoxal were unsuccessful over a wide range of pH values. In an ethanol-water system, the amidine-glyoxal addition product (19) was obtained. This adduct, which appears to be the first of its type observed, is a labile compound which turned dark on storage at room temperature, but which gave a molecular ion in the mass spectral analysis. Its further reaction with trichloroacetamidine to give 20 was attempted in various solvents under acid catalysis. In all cases, the solutions turned dark due to the decomposition of 19, and no products could be isolated. Attempts to convert 19 to its diacetate derivative, which should also be capable of condensation with the amidine, were also unsuccessful due to extensive decomposition.

In order to obtain a more stable reaction intermediate than 19, trichloroacetamidine was condensed with oxalyl chloride to give the dione (21), isolated as the hydrochloride salt. Experiments are underway to condense this compound with trichloroacetamidine to give the bicyclic product (22), in analogy to a similar reaction conducted with benzamidine[7].

We have previously reported the synthesis of the tetrazabicyclic compound (24) by stepwise condensation of methylenebisacetamide with glyoxal[6,8]. Similar reactions are now underway aimed at the synthesis of trihalomethyl substituted bicyclic systems such as 25, starting with the known trifluoromethyl[9] and trichloromethyl[10] substituted bisamides 26 and 27.



24



25

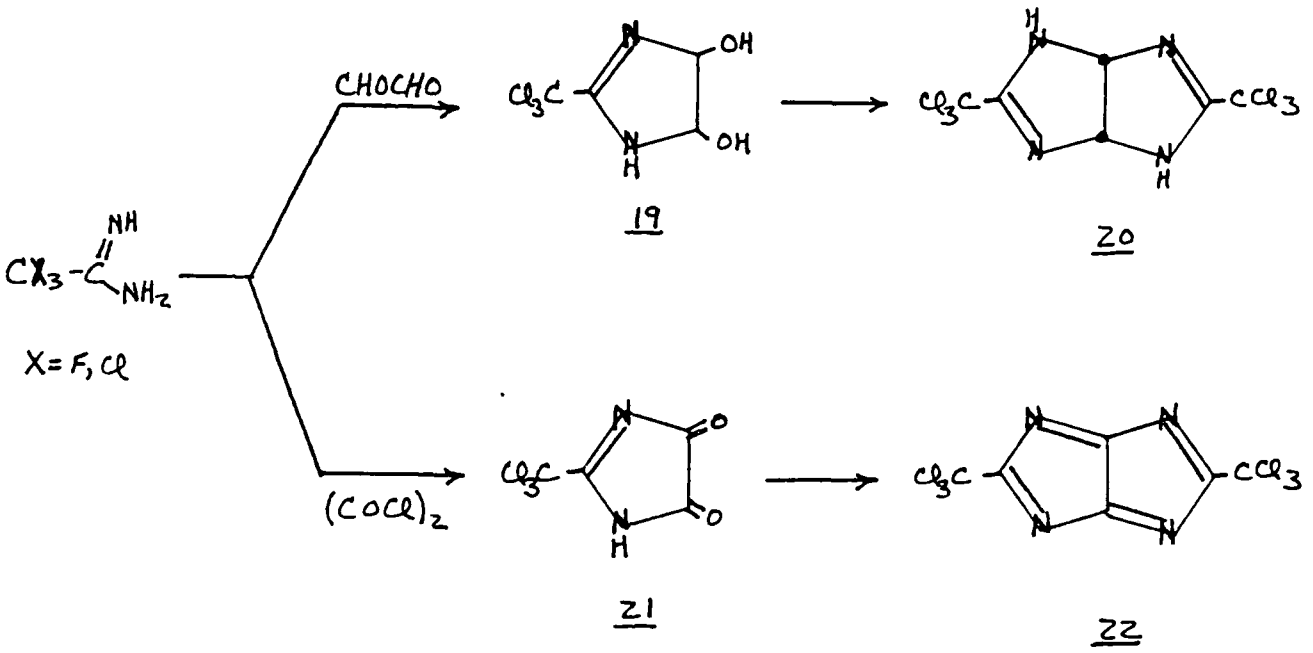
$CF_3CH(NHCHO)_2$

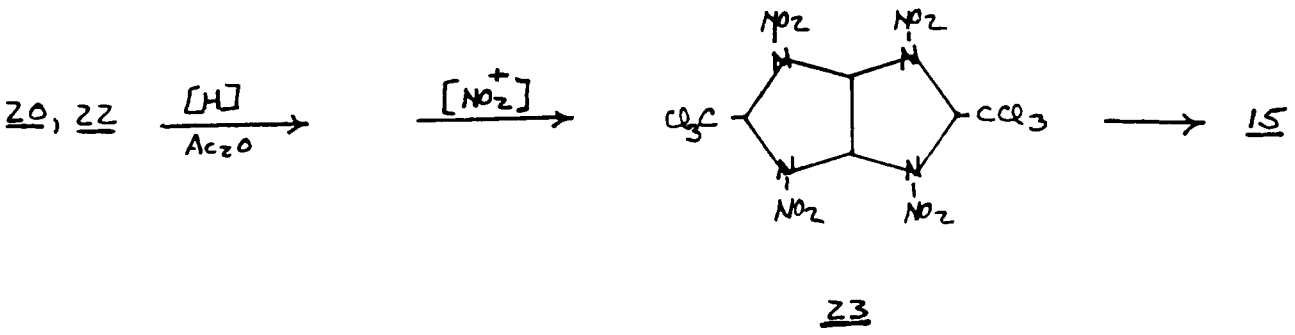
26

$CCl_3CH(NHAc)_2$

27

Scheme 1





EXPERIMENTAL SECTION

Melting points are uncorrected. Temperatures are in °C. Microanalyses are by Galbraith Laboratories, Knoxville, Tennessee. NMR spectra were obtained in part on a Varian EM-390 spectrometer, in part on a Varian XL-200 NMR spectrometer. Chemical shifts are in ppm relative to TMS internal standard.

4,8,-Diazido-3,7-dioxo-2,6-diazabicyclo[3.3.0]octane(6). - A solution of 4 (2.98g, 10 mmol) and lithium azide (4.90g, 100 mmol) in DMSO (25mL) was stirred at room temperature for 26 h, then poured into a mixture of ice and water (125mL). After stirring for 30 min in an ice bath, the precipitate was filtered to yield 1.50g of white solid: mp 208-210°C (dec). Cooling the filtrate overnight in a refrigerator gave an additional 0.145g of solid. The total yield was 74%. Recrystallization from ethanol gave colorless needles: mp 220-210°C (dec); IR (KBr), 2280 (w, sh), 2240 (w, sh), 2135 (s, N_3), 2115 (s, N_3), 1710 cm^{-1} (s, CO); ^1H NMR (CF_3CO_2H) δ 8.33 (br s, 2H, NH), 4.63 (d, 4H, CHN_3 and CHN) ppm; mass spectrum (CI, CH_4) m/z 263 (M+41, 0.9), 251 (M+29, 8.6), 223 (M+1, 18.7), 97 (100). Anal. Calcd. for $C_6H_6N_8O_2$: C, 32.43; H, 2.72; N, 50.44. Found: C, 32,18; H, 2.89; N, 49.26.

4,8-Diazido-2,6-dinitro-3,7-dioxo-2,6-diazabicyclo[3.3.0]octane(7). - Acetic anhydride (1.0 mL) was cooled to 0°C and absolute (98%) nitric acid (1.0 mL) was then added dropwise, with stirring, over 2 min. After 20 min, 6 (666mg, 3.0 mmol) was added all at once and stirring was continued at 0°C for 2h. The solution was then poured into a mixture of ice cold water (15 mL) and the precipitate filtered immediately and dried over P_2O_5 under vacuum to yield 440mg (47%) of white solid: mp 123-124°C (dec); IR (KBr), 2140 (s), 1782 (s), 1590 (s), 1265 (s), 1158cm^{-1} (s); ^1H NMR (Me_2CO-d_6) δ 5.42 (s, 4H, CHN_3 and CHN) ppm; mass spectrum (CI, CH_4) m/z 353 (M+41, 0.1), 341 (M+29, 0.2), 313 (M+1, 0.55), 95 (50), 48 (48), 44 (100).

4,8-Dibromo-2,6-dimethyl-3,7-dioxo-2,6-diazabicyclo[3.3.0]octane(10). - A mixture of 9 (1.41g, 3.0 mmol) and aqueous HBr (15 mL of 5N) was refluxed for 3 h and the resulting solution was then evaporated under vacuum. The yellow residue was dissolved in a mixture of acetone (10 mL) and ether (3 mL) and cooled in a refrigerator overnight to deposit 660mg (67.5%) of a white solid: mp 216-218°C (dec). Recrystallization from ethanol gave colorless crystals: mp 220-222°C (dec); ^1H NMR ($CDCl_3$) δ 3.01 (s, 6H, CH_3), 4.41 and 4.52 (2s, 4H, CHBr and CHN) ppm; Anal. Calcd. for $C_8H_{10}BR_2N_2O_2$: C, 29.47; H, 3.09; N, 8.59; Br, 49.03. Found: C, 29.76; H, 3.04; N, 8.58; Br, 47.02.

2,6-Dimethyl-4,8-dinitro-3,7-dioxo-2,6-diazabicyclo[3.3.0]octane(12). - A mixture of 11 (3.6g, 8.96 mmol) and 2N NaOH (22 mL) was stirred in an ice bath for 30 min and then with the bath removed for 90 min. The solution was again cooled in ice during the dropwise addition of 12N HCl (5 mL) over 5 min. After stirring at 0°C for 20 min, the mixture was filtered to yield 1.44g (62.3%) of white solid: mp 212-215°C (dec). Recrystallization from CH_3CN gave colorless crystals: mp 239-240°C (dec); ^1H NMR (CF_3CO_2H) δ 5.81 (m, 2H, $CHNO_2$), 5.39 (m, 2H, CHN), 3.31 (s, 6H, CH_3) ppm; mass spectrum (CI, CH_4) m/z 299 (M+41, 4.5), 287 (M+29, 5.6), 259 (M+1, 100); Anal. Calcd. for $C_8H_{10}N_4O_6$: C, 37.21; H, 3.90; N, 21.70. Found: C, 37.38; H, 3.98; N, 21.64.

4,5-Diacetoxy-1,3-Dinitroimidazolidine(17). - Concentrated H_2SO_4 (0.3 mL) was

slowly added dropwise to a stirred mixture of methylenedinitramine (1.36g, 10 mmol), 40% aqueous glyoxal (1.6g, 11 mmol) and water (0.5 mL). The mixture was then slowly heated to 50°C to effect solution and acetic anhydride (15 mL) was added dropwise over 10 min. After stirring at room temperature for 18h, the cloudy mixture was evaporated under vacuum to about 3 mL and extracted thoroughly with ethyl acetate. The extracts were washed with H_2O, 5% aqueous $NaHCO_3$, saturated salt solution, dried ($MgSO_4$) and evaporated to a pale yellow oil. The oil was dissolved in a minimum amount of warm 5% CH_3CN-benzene, placed on a short column of silica gel (20g) and eluted with the same solvent mixture. The first 40 mL of eluent contained the desired product. Evaporation gave a mixture of solid and oil which was triturated with a 1:1 mixture of ether and isopropyl ether (4 mL) and cooled overnight. Filtration gave 100mg (~4%) of white solid: mp 113-115°C; ^1H NMR ($CDCl_3$) δ 6.91 (s, 2H, CH), 5.79 (s, 2H, CH_2), 2.19 (s, 6H, CH_3) ppm; mass spectrum (CI, CH_4) m/z 219 (M+1-CH_3CO_2H, 26), 147 (14), 114 (43), 103 (16), 79 (19), 61 (34), 43 (100); Anal. Calcd. for $C_7H_{10}N_4O_8$: C, 30.22; H, 3.62; N, 20.14. Found: C, 30.39; H, 3.91, N, 19.89.

Trichloroacetamidine. - Trichloroacetonitrile (7.0g) was added dropwise to about 25 mL of ammonia at -40° to -50° according to a published procedure[11]. The cooling bath was removed and the ammonia allowed to reflux on a cold finger (dry ice) condenser for 1 h. The ammonia was allowed to evaporate and the residue was heated and stirred with petroleum ether (bp 38-50°). A cloudy solution was decanted from residual solid, filtered, and refrigerated to give needle crystals of the amidine, 4.83g (62%), with mp 48-9°C (lit mp[11] 47-48°).

2-Trichloromethyl-4,5-Dihydroxy-Imidazoline (19). - A solution of 4.9g (0.030 mol) of trichloroacetamidine in 7.5 mL ethanol was added dropwise to a solution of 2.2g of 40% glyoxal solution (0.015 mol) in 5 mL of water. The addition caused a temperature rise from 20° to 33°C. One hour after the addition, the flask was refrigerated at -10°C. Collection of the crystals precipitated from solution the next day gave 0.85g (26%) of the title compound: mp 107° (dec.); IR (KBr) 3400 (br, NH, OH) and 1610 (C=N) cm^{-1}; NMR (d_6 - acetone) δ 5.5 (s, C-H); mass spectrum, m/z (rel intensity) 219, 221, 223 (4.7, 4.5, 1.6 for M+1), 247, 249, 251 (0.3, 0.2, 0.2 for M+29), 259, 261, 263 (0.3, 0.4, 0.1 for M+41), 59 (100).

2-Trichloromethyl-Imidazoline-4,5-Dione Hydrochloride (21). - A solution of 1.27g (0.01 mol) of oxalyl chloride in 3 mL of carbon tetrachloride was added dropwise to 1.61g (0.01 mol) trichloroacetamidine in 5 mL carbon tetrachloride. The resultant thick mixture of precipitate and solution was heated in a 65-70°C bath for 3 h. The solid was isolated by filtration, washed with carbon tetrachloride, and dried under vacuum at 20°C to give 1.73g (75%) of the title compound with mp 200°-203°C (lit[12] mp 194°C).

References

1. Adolph, H. G.; Chaykovsky, M.; Goldwasser, J. M.; Koppes, W. M. "Synthesis of Energetic Materials," Annual Progress Report for the Office of Naval Research, March, 1986; Naval Surface Weapons Center, Silver Spring, MD 20903-5000.

2. Kornblum, N.; Larson, H. O.; Blackwood, R. K.; Mooberry, D. D.; Oliveto, E. P.; Graham, G. E. J. Am. Chem. Soc., 1956, 78, 1497.

3. Kornblum, N.; Blackwood, R. K.; Powers, J. W. J. Am. Chem. Soc., 1957, 79, 2507.

4. Kornblum, N.; Singh, H. K.; Kelly, W. J. J. Org. Chem., 1983, 48, 332.

5. Garver, L. C.; Grakauskas, V.; Baum, K. J. Org. Chem., 1984, 50, 1699.

6. Adolph, H. G.; Chaykovsky, M.; Goldwasser, J. M.; Koppes, W. M. "Synthesis of Energetic Materials", Annual Progress Report for the Office of Naval Research, March 1984, Naval Surface Weapons Center, Silver Spring, MD 20903-5000.

7. Kwasnik, H. R.; Oliver, J. E.; Brown, R. T. J. Heterocycl. Chem., 1972, 9, 1429.

8. Koppes, W. M.; Chaykovsky, M.; Adolph, H.; Gilardi, R.; George, C. J. Org. Chem., 1987, 52, 1113.

9. Krimmel, J. A.; Schmidt-Collerus, J. J.; Young, J. A.; Bohner, G. E.; Gray, D. M. J. Org. Chem., 1971, 36, 350.

10. Zygmunt, E.; Grochowski, Przemysl. Chem., 1959, 38, 693.

11. Albert, A.; Paal, B. Chem. Ind., 1974, 874.

12. Samarai, L. I.; Belaya, V. P.; Bondar, V. A.; Derkach, G. I. Dopdv. Akad. Nauk UKR. RSR, SER. B1968, 30, 1024.

Distribution

Prof. J. H. Boyer
Chemistry Department
University of New Orleans
New Orleans, Louisiana 70148

Prof. J. C. Chien
University of Massachusetts
Department of Polymer Sciences
and Engineering
Amherst, MA 03003

Dr. M. B. Frankel
Rockwell International
Rocketdyne Division
6633 Canoga Avenue
Canoga Park, CA 91304

Dr. R. A. Earl
Hercules, Inc.
Magna, Utah 84109

Dr. W. H. Graham
Morton Thiokol, Inc.
Huntsville Division
Huntsville, AL 35807-7501

Dr. C. Coon
Lawrence Livermore Lab.
P. O. Box 808
Livermore, CA 94550

Dr. R. Gilardi
Naval Research Laboratory
Code 6030
Washington, D. C. 20375

Dr. A. Marchand
Dept. of Chemistry
North Texas State University
KTSU Station, Box 5068
Denton, TX 76203-5068

Director
US Army Ballistic Research Lab
ATTN: DRXBR-IBD
Aberdeen Proving Ground, MD 21005

Dr. Robert R. Ryan
INC-4, C346
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Dr. M. Farber
Space Sciences, Inc.
135 W. Maple Avenue
Monrovia, CA 91016

Mr. C. M. Havlik
0/83-10, B/157-3W
Lockheed Missiles & Space Co., Inc.
P.O. Box 504
Sunnyvale, CA 94086

Dr. Philip Howe
Ballistic Research Laboratory
Code DRXBR-TBD
Aberdeen Proving Ground, MD 21005

Prof. C. Sue Kim
Department of Chemistry
California State University, Sacramento
Sacramento, CA 95819

Dr. R. Reed Jr.
Naval Weapons Center
Code 38904
China Lake, CA 93555

Dr. Kurt Baum
Fluorochem, Inc.
480 South Ayon Ave.
Azusa, CA 91702

Dr. R. A. Hollins
Naval Weapons Center
Code 3853
China Lake, CA 93555

Dr. P. E. Eaton
Department of Chemistry
University of Chicago
5735 South Ellis Avenue
Chicago, IL 50537

Head, Chemistry Division
Office of Naval Research
Code 1113
Arlington, VA 22217

Dr. Andrew C. Victor
Naval Weapons Center
Code 3208
China Lake, CA 93555

Distribution (Cont.)

Dr. R. Atkins
Naval Weapons Center
Code 385
China Lake, CA 93555

Dr. H. Rosenwasser
Naval Air Systems Command
AIR-320R
Washington, D. C. 20361

Dr. James T. Bryant
Naval Weaopns Center
Code 3205B
China Lake, CA 93555

Dr. L. Rothstein
Assistant Director
Naval Explosives Dev. Engr. Dept.
Naval Weapons Station
Yorktown, VA 23691

Dr. Henry Webster, III
Manager, Chemical Sciences Branch
ATTN: Code 5063
Crane, IN 47522

Dr. Arpad Juhasz
Code DRDAR-IBD
Ballistic Research Lab
Aberdeen, MD 21005

Dr. Robert J. Schmitt
SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025

Naval Sea Systems Command
ATTN: Dr. J. K. Kilroy
NAVSEA 62D3
Crystal Plaza, Bldg. 5, Rm 806
Washington, D. C. 20362

Dr. A. J. Matuszko
Air Force Office of Scientific Research
Directorate of Chemical & Atmospheric Sciences
Bolling Air Force Base
Washington, D. C. 20332

Dr. A. Nielsen
Naval Weapons Center
Code 385
China Lake, CA 93555

Defense Technical Info. Ctr.
Bldg. 5, Cameron Station
Alexandria, VA 22314
(12 copies)

Dr. M. D. Coburn
Los Alamos National Lab
M-1, Mail Stop C920
Los Alamos, NM 87545

Dr. L. H. Caveny
Air Force Office of Scientific Research
Directorate of Aerospace Sciences
Bolling Air Force Base
Washington, D. C. 20332

W. G. Roger
Code 5253
Naval Ordnance Station
Indian Head, MD 20640

Dr. Donald L. Bell
Air Force Office of Scientific Research
Directorate of Chemical and Atmospheric Sciences
Bolling Air Force Base
Washington, D. C. 20332

U. S. Army Research Office
Chemical & Biological Sciences Division
P. O. Box 12211
Research Triangle Pk, NC 27709

G. Butcher
Hercules, Inc.
MS X2H
P. O. Box 98
Magna, Utah 84044

J. J. Rocchio
USA Ballistic Research Lab
Aberdeen Proving Ground, MD 21005-5066

Distribution (Cont.)

G. A. Zimmerman
Aerojet Tactical Systems
P. O. Box 13400
Sacramento, CA 95813

Dr. J. R. West
Morton Thiokol, Inc.
P. O. Box 30058
Shreveport, LA 71130

Director Naval Research Laboratory
ATTN: Code 2627
Washington, D. C. 20375
(6 copies)

Dr. L. Dickinson
Naval Explosive Ordnance
Disposal Tech. Center
Code D
Indian Head, MD 20340

Dr. D. Mann
U. S. Army Research Office
Engineering Division
Box 12211
Research Triangle Pk, NC 27709-2211

R. Geisler
ATTN: DY/MS-24
AFRPL
Edwards AFB, CA 93523

Dr. Janet Wall
Code 012
Director, Research Admin.
Naval Postgraduate School
Monterey, CA 93943

G. Edwards
Naval Sea Systems Command
Code 52D32
Washington, D. C. 20362

Dr. E. H. deButts
Hercules Aerospace Co.
P. O. Box 27408
Salt Lake City, UT 84127

D. A. Flanigan
Director, Advanced Technology
Morton Thiokol, Inc.
Aerospace Group
110 North Wacker Drive
Chicago, IL 60606

Dr. R. Peters
Aerojet Strategic Propulsion Co.
Bldg. 05025 - Dept. 5400
MS 167
Sacramento, CA 95813

Dr. David C. Sayles
Ballistic Missle Defense
Advanced Technology Center
P. O. Box 1500
Huntsville, AL 35807

Naval Air Systems Command
ATTN: Mr. B. P. Sobers
NAVAIR-320G
Jefferson Plaza 1, RM 472
Washington, D. C. 20361

Dr. D. Dillehay
Morton Thiokol, Inc.
Longhorn Division
Marshall, TX 75670

Dr. G. Thompson
Morton Thiokol, Inc.
Wasatch Division
MS 240 P. O. Box 524
Bringham City, UT 84302

Dr. R. S. Miller
Office of Naval Research
Code 1132P
Arlington, VA 22217
(10 copies)

JHU Applied Physics Laboratory
ATTN: CPIA (T. W. Christian)
Johns Hopkins Road
Laurel, MD 20707

Distribution (Cont.)

Dr. K. D. Hartmann
Hercules Aerospace Division
Hercules Incorporated
Alleghany Ballistic Lab.
P. O. Box 210
Washington, D. C. 21502

O. K. Heiney
AFATL-DLJG
Eglin AFB, FL 32542

Dr. M. K. King
Atlantic Research Corp.
5390 Cherokee Avenue
Alexandria, VA 22312

R. B. Steele
Aerojet Strategic Propulsion Co.
P.O. Box 15699C
Sacramento, CA 95813

E. S. Sutton
Thiokol Corporation
Elkton Division
P.O. Box 241
Elkton, MD 21921

L. C. Estabrook, P. E.
Morton Thiokol, Inc.
P.O. Box 30058
Shreveport, LA 71130

Dr. A. L. Slafkosky
Scientific Advisor
Commandant of the Marine Corps
Code RD-1
Washington, D.C. 20380

Dr. H. P. Marshall
Dept. 93-50, Bldg. 204
Lockheed Missile & Space Co.
3251 Hanover Street
Palo Alto, CA 94304

Dr. I. W. May
Army Ballistic Research Lab.
ARRADCOM
Code DRXBR - 1BD
Aberdeen Proving Ground, MD 21005

Commander
US Army Missile Command
ATTN: DRSMI-RKL
Walter W. Wharton
Redstone Arsenal, AL 35898

Dr. R. L. Derr
Naval Weapons Center
Code 389
China Lake, CA 93555

T. Boggs
Naval Weapons Center
Code 389
China Lake, CA 93555

END

DATE

FILMED

3-88

DTIC