Anal. Calcd. for $C_9H_{18}N_2O_4$: C, 49.52; H, 8.31; N, 12.87. Found: C, 49.50; H, 8.41; N, 12.87.

Preparation of Dibromodinitroparaffins.—Several γ-dinitroparaffins were derivatized by reaction with bromine under basic conditions to give the dibromo compound. This was accomplished by first dissolving the dinitroparaffin in saturated alcoholic sodium hydroxide, pouring this solution into 10% aqueous sodium hydroxide and adding an equivalent amount of bromine. The dibromo compound which precipitated rapidly was recrystallized from a mixture of methanol and water. The derivatives prepared are listed in Table II.

TABLE II

DIBROMO DERIVATIVES OF γ-DINITROALKANES

Derivative	M.p., °C.	Analyses, % Carbon Calcd.	Carbon Found	Hydrogen Calcd.	Hydrogen Found
$(C_2H_5CBrNO_2)_2CH_2$	75	24.16	24.27	3.48	3.50
$(n\text{-}C_3H_7CBrNO_2)_2CH_2$	105–106	28.74	28.93	4.29	4.24
$[(CH_3)_2CHCH_2CBrNO_2]_2CH_2$	127	32.69	32.74	4.99	5.16
$(n\text{-}C_5H_{11}CBrNO_2)_2CH_2$	84	39.14	39.38	6.13	6.29

WEST LAFAYETTE, INDIANA

[CONTRIBUTION FROM DEFENCE RESEARCH CHEMICAL LABORATORIES]

A New Molecular Rearrangement Involving Carbonium Ions[1]

BY A. F. McKAY[2] AND J. R. GILPIN

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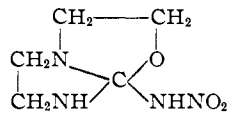
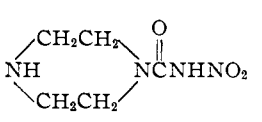
1-(β-Hydroxyethyl)-2-nitriminoimidazolidine in the presence of thionyl chloride rearranges to 1-nitro-2-keto-1,3,6-triazacycloöctane. Another structural isomer of (1-(β-hydroxyethyl)-2-nitriminoimidazolidine, 1-(β-nitraminoethyl)-2-imidazolidone, also is obtained. This new molecular rearrangement is explained as proceeding through carbonium ion intermediates. A new method has been developed for the preparation of 1-substituted-2,3,5,6-tetrahydro-1-imidaz[1,2-a]imidazoles.

Three compounds have been isolated from the chlorination of 1-(β-hydroxyethyl)-2-nitriminoimidazolidine[3,4] with thionyl chloride. One of these compounds was the expected 1-(β-chloroethyl)-2-nitriminoimidazolidine (VII) which melted at 143.5°. The other two white crystalline compounds melted at 182 and 206.5°, respectively. The compound melting at 182° gave analytical values in agreement with the empirical formula $C_5H_{10}N_4O_3$, which identified it as a structural isomer of the starting material 1-(β-hydroxyethyl)-2-nitriminoimidazolidine (V) (m.p. 132.5°).

The structural isomers of compound V are I, II, III, IV, IX, X and XI. The ultraviolet absorption



I



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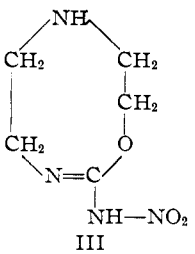
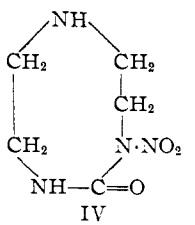


III



IV

spectrum of compound A[5] has a single maximum at a wave length of 235 mμ with a molar extinction coefficient of 5970. This eliminates structures II and III for compound A because nitroureas[6–8] possess a maximum at a wave length of about 260 mμ with a molar extinction coefficient between 9,000 and 12,000. Since compound A gives a negative color reaction with dimethylaniline in the Franchimont test,[9,10] structures IV, IX and XI are excluded. Finally structures I, IV, IX and XI are eliminated by the infrared spectrum of compound A. The infrared spectrum of compound A displays two N–H stretching bands at 3220 cm.$^{-1}$ and 3105 cm.$^{-1}$ as well as N–H deformation bands at 1573 and 1520 cm.$^{-1}$. It has a band at 1540 cm.$^{-1}$ attributed[11,12] to the NNO_2 group and a band at 1330 cm.$^{-1}$ characteristic of symmetrical nitro group vibrations. A very strong band appears at 1672 cm.$^{-1}$ indicative of a ureido carbonyl group. The ureido carbonyl band is displaced to higher wave numbers (1745–1760 cm.$^{-1}$)[12] when the adjacent nitrogen is substituted with a nitro group as in structure IV and XI. All of the bands exhibited by the spectrum of compound A would be expected for 1-(β-nitraminoethyl)-2-imidazolidone, which is the only structure left for compound A.[13]

Compound B (m.p. 206.5°) gives a deep green color with dimethylaniline in the Franchimont test. It gives a positive test for ionic chlorine and forms a picrate (m.p. 197–198°). Its analysis showed it to be a hydrochloride of a compound having the empirical formula $C_5H_{10}N_4O_3$. Thus this third

(1) Issued as D. R. C. L. Report No. 171.

(2) Monsanto Canada Limited, Ville LaSalle, Quebec.

(3) A. F. McKay, J. R. G. Bryce and D. E. Rivington, *Can. J. Chem.*, **29**, 382 (1952).

(4) This compound was formerly referred to as 1-(β-hydroxyethyl)-2-nitramino-2-imidazoline. It actually exists as a resonance hybrid with the nitrimino form being one of the extreme contributing structures; *cf.* A. F. McKay, M. A. Weinberger, J. P. Picard, W. G. Hatton, M. Bedard and H. E. Rooney, THIS JOURNAL, **76**, 6371 (1954).

(5) The compound melting at 182° will be referred to as compound A, while the one melting at 206.5° will be referred to as compound B, for convenience.

(6) A. F. McKay, J. P. Picard and P. E. Brunet, *Can. J. Chem.*, **29**, 746 (1951).

(7) A. F. McKay and C. Sandorfy, *ibid.*, **31**, 42 (1953).

(8) M. A. Weinberger and A. F. McKay, THIS JOURNAL, **77**, 1321 (1955).

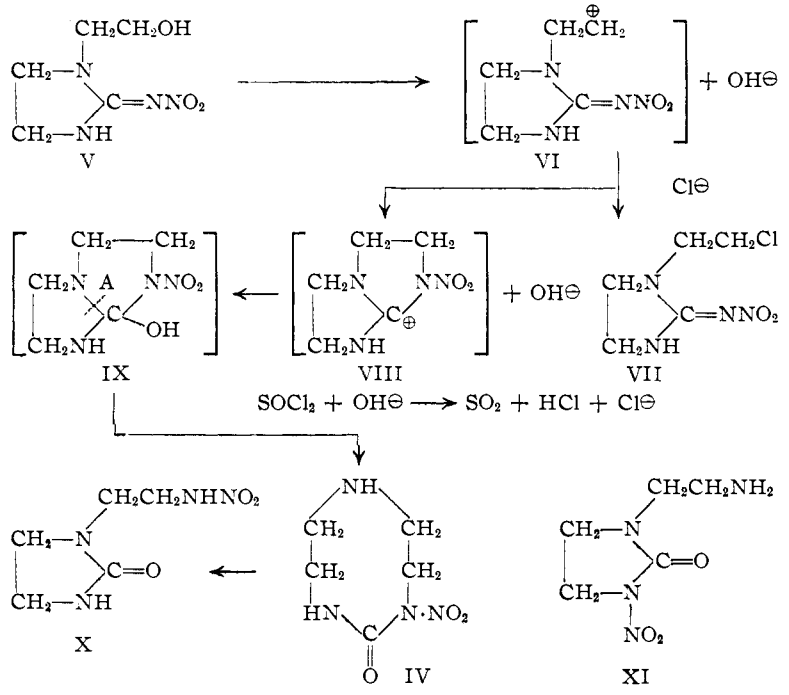
(9) A. P. N. Franchimont, *Rec. trav. chim.*, **16**, 213 (1897).

(10) A. F. McKay, *Chem. Revs.*, **51**, 301 (1952).

(11) E. Lieber, D. R. Levering and L. J. Patterson, *Anal. Chem.*, **23**, 1594 (1951).

(12) A. F. McKay, C. E. Hubley and C. Sandorfy, in preparation.

(13) 1-(β-Nitraminoethyl)-2-imidazolidone has been synthesized and it has been shown to be identical with compound A by a comparison of their physical properties and by a mixed melting point determination. This synthesis will be reported at a later date.

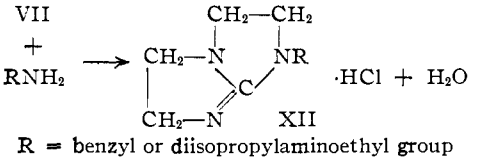


compound is also an isomer of the starting material 1-(β-hydroxyethyl)-2-nitriminoimidazolidine (V). Similar arguments to those used above to determine the structure of compound A eliminate all but structures IV and XI for compound B. The infrared spectrum of compound B taken in potassium bromide pellets possesses a N–H stretching band at 3450 cm.$^{-1}$ and possible deformation band at 1573 cm.$^{-1}$. The strong band at 1760 cm.$^{-1}$ indicates the presence of a C=O group. The high wave number for the C=O stretching band can be attributed to an adjacent NO_2 group in position 3 and/or its presence in a strained ring. A band is present at 1328 cm.$^{-1}$ which is in the right location for a nitro group symmetrical vibration. None of this evidence clearly distinguishes between structures IV and XI for compound B. However the hydrochloride of compound XI would not be expected to give a band at 3450 cm.$^{-1}$, whereas the hydrochloride of structure IV could give a band in this region. The final choice between these two structures must await the development of further evidence.[13a]

The rearrangement of 1-(β-hydroxyethyl)-2-nitriminoimidazolidine (V) to 1-(β-nitraminoethyl)-2-imidazolidone (X) is explained by a series of steps involving the carbonium ions VI and VIII. Addition of an OH^- ion to carbonium ion VIII gives the unstable intermediate IX which by ring opening at A gives 1-nitro-2-keto-1,3,6-triazacycloöctane. This reaction presents more indirect evidence in support of the addition-elimination mechanism used[10] to explain some of the reactions of nitroguanidines and substituted nitrosonitroguanidines with amines. The depicted step wise reaction mechanism is used for convenience in presentation. It is realized that several of these steps may occur instantaneously. Moreover, a slightly different reaction mechanism could be used to explain the above results. However, additional evidence has been accumulated on a related reaction which supports the above arguments.[13b]

The chlorination of 1-(β-hydroxyethyl)-2-nitriminoimidazolidine is indicated as involving the addition of the Cl^- to the carbonium ion VI, the Cl^- being released from the thionyl chloride by reaction with the liberated hydroxyl ion.

The original aim of this work was to develop a new method of preparing 1-substituted-2,3,5,6-tetrahydro-1-imidaz[1,2-a]imidazoles (XII). Since cyclic nitroguanidine derivatives have been shown[14–15b] to give 2-substituted amino-Δ^2-1,3-diazacycloalkenes on heating with amines under anhydrous conditions, it was expected that the nitrimino group of 1-(β-chloroethyl)-2-nitriminoimidazolidine could be replaced in a similar manner. Then cyclization through the active β-chloroethyl group would complete the reaction to give the desired bicyclic compound XII as



R = benzyl or diisopropylaminoethyl group

These reactions did occur and 1-benzyl- and 1-diisopropylaminoethyl-2,3,5,6-tetrahydro-1-imidaz-[1,2-a]imidazoles were prepared in this manner.

1-Benzyl-2,3,5,6-tetrahydro-1-imidaz[1,2-a]imidazole (m.p. 39.5–40°) possessed no hypnotic effect below its toxic level (LD_{50} 29 mg./kg. in water). The LD_{50} for 1-(β-diisopropylaminoethyl)-2,3,5,6-tetrahydro-1-imidaz[1,2-a]imidazole in water was 43 mg./kg. These toxicities were determined with rats by intraperitoneal injection.

Experimental[16]

1-(β-Hydroxyethyl)-2-nitriminoimidazolidine.—The yield of 1-(β-hydroxyethyl-2-nitriminoimidazolidine[3] has been in-

(13a) 1-β-(Aminoethyl)-3-nitro-2-imidazolidone (XI) and 1-nitro-2-keto-1,3,6-triazacycloöctane (IV) have been synthesized and compound B was found to be identical with 1-nitro-2-keto-1,3,6-triazacycloöctane by a comparison of their physical properties. A mixed melting point determination on their picrates gave no depression. The picrate of compound XI melts at 134.5–135°.

(13b) NOTE ADDED IN PROOF.—Since primary nitramines are unstable in acid solution or in the presence of acid chlorides,[10] it is unlikely that 1-(β-nitraminoethyl)-2-imidazolidone (X) forms in the presence of thionyl chloride. This product is most likely formed during the isolation of the products. In support of this contention, it was observed that 1-nitro-2-keto-1,3,6-triazacycloöctane nitrate on refluxing with alcohols was converted into 1-(β-nitraminoethyl)-2-imidazolidone (X). It also is considered that the OH^- group must remain within the reaction zone of the molecule to participate in this rearrangement, otherwise it would be destroyed by the thionyl chloride.

(14) A. F. McKay, M. N. Buchanan and G. A. Grant, THIS JOURNAL, **71**, 766 (1949).

(15) (a) A. F. McKay, J. R. Coleman and G. A. Grant, *ibid.*, **72**, 3205 (1950); (b) A. F. McKay and W. G. Hatton, *ibid.*, **75**, 963 (1953).

(16) All melting points were taken on a Kofler block. Microanalyses were performed by Micro-Tech Laboratories, Skokie, Ill.

creased from 42 to 56.7% by the following modification in procedure. 1-Amino-5-hydroxy-3-azapentane (50.8 g., 0.48 mole) was added dropwise over a period of 30 minutes to a stirred suspension of 62.6 g. (0.426 mole) of methylnitrosonitroguanidine[17,18] in 150 cc. of water. The temperature was held below 20° during the addition period and then the reaction mixture was stirred for a further two hours at 4°. The white crystals (m.p. 129–131°) were removed by filtration, yield 22.9 g. When the filtrate was reduced to one-third its original volume *in vacuo*, a second crop of crystals (m.p. 129–130.5°) was obtained, yield 19.0 g. One crystallization from 95% ethanol raised the melting point to 131.5–132.5°.

Reaction of 1-(β-Hydroxyethyl)-2-nitriminoimidazolidine with Thionyl Chloride.—A suspension of 1-(β-hydroxyethyl)-2-nitriminoimidazolidine (58.0 g., 0.333 mole) in anhydrous benzene (450 cc.) was treated with thionyl chloride (43.6 g., 0.366 mole). This mixture was held at 41–58° for approximately 8.5 hours. The resulting hygroscopic solid was fractionally crystallized from absolute ethanol. One of the white crystalline products melted at 142.5–143.5° and it possessed the properties expected for 1-(β-chloroethyl)-2-nitriminoimidazolidine, yield 31.12 g. (48.4%). *Anal.* Calcd. for $C_5H_9ClN_4O_2$: C, 31.18; H, 4.71; Cl, 18.41; N, 29.09. Found: C, 31.17; H, 4.60; Cl, 18.92; N, 28.84. Another product, which was also a white crystalline solid, melted at 173–180°, yield 15.06 g. (26.0%). After two crystallizations from absolute ethanol, its melting point was increased to 180–182.5° dec. Its ultraviolet absorption spectrum showed a maximum at 235 mμ with a molar extinction coefficient of 5970 (1.6×10^{-5} mole/liter in 95% ethanol). This compound gave a feeble positive color reaction with α-naphthylamine in the Franchimont[9] test.

Anal. Calcd. for $C_5H_{10}N_4O_3$: C, 34.49; H, 5.78; N, 32.15. Found: C, 34.77; H, 5.63; N, 32.23.

The final filtrate from these two products was evaporated to dryness under reduced pressure on a steam-bath. The residual dark amber oil was extracted with dry benzene (50 cc.), which caused another white crystalline product to separate. This crystalline material was removed by filtration and washed with ethanol (20 cc.), yield 0.78 g. (1.9%). The melting point was raised from 195–197° dec. to 205.5–206.5° dec. by two crystallizations from absolute ethanol. It gave a positive test for ionic chlorine and a deep green color with dimethylaniline in the Franchimont test.[9]

Anal. Calcd. for $C_5H_{11}ClN_4O_3$: C, 28.50; H, 5.22; Cl, 16.85; N, 26.58. Found: C, 28.64; H, 5.11; Cl, 17.27; N, 26.68.

A picrate of the latter compound formed in the usual manner melted at 197.5–198.5°.

Anal. Calcd. for $C_{11}H_{13}N_7O_{10}$: C, 32.80; H, 3.22; N, 24.32. Found: C, 32.82; H, 3.33; N, 24.30.

1-Benzyl-2,3,5,6-tetrahydro-1-imidaz[1,2-a]imidazole.—1-(β-Chloroethyl)-2-nitriminoimidazolidine (6.95 g., 0.036 mole) and benzylamine (19.35 g., 0.18 mole) in toluene (180 cc.) were refluxed for 9.5 hours. After the toluene was removed *in vacuo*, the residual oil was fractionated in a Späth bulb at reduced pressure (0.003 mm.). This fractionation gave 1.70 g. of colorless oil, an intermediate fraction of 1.14 g., and a high boiling fraction (>155°) of 4.16 g. (57.4%). The high boiling oil gave a picrate (m.p. 107–109°) which on purification by crystallization from water melted at 109–109.5°. This picrate analyzed correctly for the picrate of 1-benzyl-2,3,5,6-tetrahydro-1-imidaz[1,2-a]imidazole.

Anal. Calcd. for $C_{18}H_{18}N_6O_7$: C, 50.23; H, 4.23; N, 19.52. Found: C, 50.46; H, 4.27; N, 19.95.

A picrate (m.p. 198–200.5°) was prepared from the low boiling oil (1.70 g.) in the usual manner. It was purified by crystallization from water and identified as benzylamine picrate by a mixed melting point determination with an authentic sample.

A larger run using 13.9 g. (0.07 mole) of 1-(β-chloroethyl)-2-nitriminoimidazolidine and 38.7 g. (0.36 mole) of benzylamine under similar reaction conditions gave 6.98 g. (48.2%) of colorless oil (b.p. 128–131° (0.11 mm.); $n^{26.0}D$ 1.56963). This oil solidified on standing into hygroscopic crystals which melted at 39–40.5° in a closed tube.

Anal. Calcd. for $C_{12}H_{15}N_3$: C, 71.71; H, 7.52; N, 20.87. Found: C, 71.43; H, 7.85; N, 20.60.

A picrate of the crystalline solid melted at 107.5–108° alone and on admixture with an authentic sample of the picrate (m.p. 109–109.5°) of 1-benzyl-2,3,5,6-tetrahydro-1-imidaz[1,2-a]imidazole.

N,N-Diisopropylethylenediamine.—Bromoethylphthalimide[19] (23.0 g., 0.09 mole) and diisopropylamine (19.4 g., 0.19 mole) were sealed in a 75-cc. tube and heated for four days in a steam jacket. After the tube was opened, the unreacted diisopropylamine was removed *in vacuo*. The residue was treated with 6.4 cc. of concentrated hydrobromic acid solution (42%). This treatment gave a suspension of crystals which were removed by filtration. The solid on the filter, which consisted of a mixture of unchanged N-bromoethylphthalimide and the desired N-diisopropylaminoethylphthalimide hydrobromide was heated with 200 cc. of water on a steam-bath. The clear solution was decanted from insoluble oil. This insoluble oil soon solidified and it was identified as unreacted N-β-bromoethylphthalimide, yield 7.11 g. The filtrate from the unreacted N-β-bromophthalimide was combined with the original filtrate and the combined solution evaporated to dryness. On crystallizing the residue from water (50 cc.) a 51.7% (16.65 g.) yield of N-β-diethylaminoethylphthalimide hydrobromide (m.p. 240–243°) was obtained.

N-Diisopropylaminoethylphthalimide (14.07 g., 0.05 mole) in a 1:1 solution of hydrobromic acid (42%) and water (70 cc.) was refluxed for three hours. On cooling to room temperature, phthalic acid separated, yield 6.30 g. (95.8%). The filtrate was evaporated to dryness and then it was redissolved in 30 cc. of water and a small trace of phthalic acid removed by filtration. The filtrate was taken to dryness and the residue was crystallized from 95% ethanol (25 cc.). This procedure gave the N,N-diisopropylethylenediamine dihydrobromide as white platelets melting at 207–209°, yield 76.7% (9.27 g.).

To prepare the free N,N-diisopropylethylenediamine, 21.05 g. (0.068 mole) of the dihydrobromide was treated with a solution of sodium hydroxide (10 g.) in water (16 cc.). The free amine was extracted with ether (5 × 25 cc.) and the ethereal solution dried over sodium hydroxide pellets. After evaporation of the ether, the residual N,N-diisopropylethylenediamine (b.p. 38° (3–4 mm.)) was distilled *in vacuo* using apparatus equipped with a Vigreux column, yield 7.26 g., (73.3%). This amine was identified by analysis of its dipicrate (m.p. 207.5° dec.) formed in the usual manner.

Anal. Calcd. for $C_{20}H_{26}N_8O_{14}$: C, 39.93; H, 4.35; N, 18.63. Found: C, 39.88; H, 4.33; N, 18.57.

1-(β-Diisopropylaminoethyl)-2,3,5,6-tetrahydro-1-imidaz[1,2-a]imidazole.—Diisopropylaminoethylamine (6.9 g., 0.047 mole) and 1-(β-chloroethyl)-2-nitriminoimidazolidine (4.6 g., 0.24 mole) in toluene (115 cc.) were refluxed for 22 hours. After heating, the excess amine and toluene were removed *in vacuo* and the residue was treated with sodium hydroxide (10 g., in 42 cc. of water) solution. This alkaline solution was extracted with ether (4 × 20 cc.) and the combined ethereal extract was dried over sodium hydroxide pellets. After evaporation of the ether, the residue was fractionally distilled under vacuum. The main fraction (b.p. 119° (0.50 mm.), $n^{24.6}D$ 1.4968) was a light yellow oil, yield 2.6 g. (45.7%). A picrate of this oil was formed in the usual manner. Its melting point was raised from 180–183° dec. to 185.5–187° dec. by two crystallizations from 50% aqueous ethanol.

Anal. Calcd. for $C_{25}H_{32}N_{10}O_{14}$: C, 43.20; H, 4.63; N, 20.10. Found: C, 43.03; H, 4.84; N, 20.00.

Acknowledgment.—The Authors are grateful to Drs. C. E. Hubley and H. H. Brownell of Defence Research Chemical Laboratories, Ottawa, Ontario, for measuring the infrared spectra and preparing the diisopropylaminoethylamine, respectively.

OTTAWA, ONTARIO

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