we have isolated 8-hydroxypenillic acid from such fermentations. When phenylacetic acid is omitted, relatively large quantities of both 6-aminopenicillanic acid and 8-hydroxypenillic can be isolated. When excess phenylacetic acid is present, both of these substances are produced but in much smaller concentrations.

The published literature reveals that 8-hydroxypenillic acid has been encountered but unrecognized by other investigators. In 1959, Tardrew and Johnson[14] reported the isolation of "Compound VI" from precursor-free *P. chrysogenum* fermentation broths. While they failed to identify the substance, they concluded that it was a stabilization product of a biosynthetic precursor of the penicillins. In the light of our findings, a review of their results leaves little doubt that "Compound VI" was 8-hydroxypenillic acid.

The fate of sulfur in *P. chrysogenum* fermentations can, therefore, be further defined

$$\begin{tikzcd}
SO_4^{=} \arrow[r] & \text{Cysteine} \arrow[r] & \text{6-APA} \arrow[r, shift left, "RCH_2COOH"] \arrow[d, "CO_2"] & \text{Penicillins} \arrow[l, shift left] \\
& & \text{8-HPA} &
\end{tikzcd}$$

The anomalous results reported recently by Steinman[15] using the manometric assay for studying the rate of 6-APA hydrolysis by penicillinase can be explained by reaction of some of the carbon dioxide with 6-APA to form 8-HPA.

It seems likely that nearly everyone working with 6-aminopenicillanic acid will, at some time, by chance or by design prepare 8-hydroxypenillic acid.

(14) P. L. Tardrew and M. J. Johnson, *J. Biol. Chem.*, **234**, 1850 (1959).

(15) H. G. Steinman, *Proc. Soc. Exptl. Biol. and Med.*, **106**, 227 (1961).

CHEMICAL DEVELOPMENT DIVISION
BRISTOL LABORATORIES DAVID A. JOHNSON
DIVISION OF BRISTOL-MYERS COMPANY
SYRACUSE 1, NEW YORK GLENN A. HARDCASTLE, JR.

RECEIVED JULY 1, 1961

A NEW GENERAL REACTION FOR PREPARING *gem* DINITRO COMPOUNDS: OXIDATIVE NITRATION

Sir:

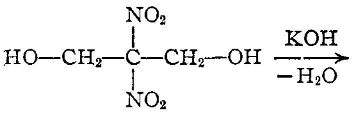
The methods available for preparing *gem* dinitro compounds are of limited applicability or are very inefficient.[1] We wish to report a new general reaction, oxidative nitration, in which salts of primary and secondary nitro compounds are converted into the corresponding *gem* dinitro derivatives by reaction with silver nitrate and inorganic nitrites in alkaline or neutral aqueous media (Equations 1 and 2). Oxidation–reduction proceeds rapidly

$$RCH{=}NO_2^- + 2Ag^+ + NO_2^- \longrightarrow RCH(NO_2)_2 + 2Ag \quad (1)$$

$$R_2C{=}NO_2^- + 2Ag^+ + NO_2^- \longrightarrow R_2C(NO_2)_2 + 2Ag \quad (2)$$

from homogeneous solution at 0–30° to yield an addition-complex which decomposes into *gem* dinitro compound and silver. Primary, secondary, and functionally-substituted dinitro compounds such as 1,1-dinitroethane, 1,1-dinitropropane, 2,2-dinitropropane, 2,2-dinitrobutane,[2a] 1,1-dinitrocyclohexane, 2,2,4,4-tetranitropentane,[2b] 2,3-dimethyl-2,4,4-trinitropentane,[2c] 2,2-dinitro-1-propanol, 1,1-dinitro-2-propanol, 2,2-dinitro-1,3-propanediol, 4,4-dinitropentanal and methyl 3,3-dinitropropionate may be prepared efficiently (60–95%) from their corresponding nitro derivatives. Sensitive or hindered compounds such as 3,3-dinitro-2-butanol,[2d] 2,2-dimethyl-1,1,3-trinitropropane[2e] and 1-cyclopropyl-1,1-dinitroethane,[2f] substances which cannot be prepared satisfactorily by other known methods, have been synthesized.

Dinitromethane has been obtained as its potassium salt from nitromethane[3] or much better from 1-nitro-2-propanol via base-catalyzed decomposition of 1,1-dinitro-2-propanol. The most practical method for preparing potassium dinitromethane (>53%) or potassium 2,2-dinitroethanol (99%) is by controlled alkaline demethylolation (Equations 3 and 4) of 2,2-dinitro-1,3-propanediol ob-



$$HO{-}CH_2{-}\overset{NO_2}{\underset{NO_2}{C}}{-}CH_2{-}OH \xrightarrow[-H_2O]{KOH} HO{-}CH_2{-}C(NO_2)_2K + CH_2{=}O \quad (3)$$

$$HO{-}CH_2{-}C(NO_2)_2K \longrightarrow CH(NO_2)_2K + CH_2{=}O \quad (4)$$

tained by oxidative nitration (70–80%) of 2-nitro-1,3-propanediol. Under different conditions 2,2-dinitro-1,3-propanediol is converted by potassium hydroxide to dipotassium 1,1,3,3-tetranitropropane[2g,4]; this salt apparently is formed by reaction of potassium dinitromethane and potassium hydroxide with 1,1-dinitroethylene[5] generated by decomposition of potassium 2,2-dinitroethanol.

Oxidative nitration of salts of 1,1-dinitro compounds does not give 1,1,1-trinitromethyl derivatives. α-Arylalkanenitronates yield *vicinal* dinitro compounds, $R_2C(NO_2)C(NO_2)R_2$, by oxidative dimerization along with carbonyl derivatives and *gem* dinitro compounds. Thus phenylnitromethane gives phenyldinitromethane (19%), benzaldehyde (36%) and *meso* and *d,l*-1,2-dinitro-1,2-diphenylethanes (12 and 25%, respectively); 9-nitrofluorene yields 9,9-dinitrofluorene (8%), fluorenone (8%), and 9,9′-dinitrodifluorenyl (76%). The effects of other functional groups on the oxidative nitration reaction are being studied.

The silver obtained may be separated easily and recovered essentially quantitatively as silver nitrate. Mercuric nitrate has been successfully sub-

---

(1) (a) G. Born, *Ber.*, **29**, 90 (1896), (b) E. ter Meer, *Ann.*, **181**, 1 (1876); J. S. Belew and L. G. Hepler, *J. Am. Chem. Soc.*, **78**, 4005 (1956); (c) W. I. Denton, R. B. Bishop, E. M. Nygaard and T. T. Noland, *Ind. Eng. Chem.*, **40**, 381 (1948); (d) C. T. Bahner, *ibid.*, **44**, 317 (1952); (e) M. G. Chancel, *Bull. soc. chim.*, **31**, 504 (1879); M. Fileti and G. Ponzio, *J. prakt. Chem.*, **55**, 195 (1897).

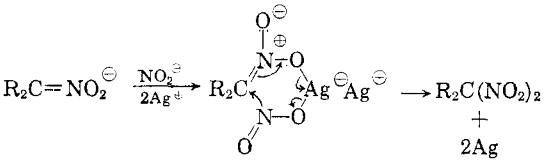
(2) New compounds: (a) b.p. 78° (10 mm.): C, 32.18; H, 5.37. (b) M.p. 87.5°: C, 23.95; H, 3.18; N, 22.39. (c) M.p. 83°: C, 36.15; H, 5.86, N, 17.71. (d) B.p. 73–75° (2 mm.): C, 29.10; H, 4.75, N, 17.02. (e) M.p. 122°: C, 29.67; H, 4.15; neut. equiv., 207. (f) B.p. 99° (10 mm.): C, 38.08; H, 4.91; N, 17.45. (g) C, 11.77; H, 0.67; N, 18.11; K, 25.50.

(3) The yield is poor because alkaline solutions of nitromethane are rapidly converted to salts of methazonic acid and because the acid, dinitromethane, is unstable.

(4) This also has been observed independently by K. Klager, Aerojet-General Corporation, Azusa, California.

(5) See L. Zeldin and H. Shechter, *J. Am. Chem. Soc.*, **79**, 4708 (1957), and M. B. Frankel, *J. Org. Chem.*, **23**, 813 (1958).

stituted for silver nitrate; however, it has the disadvantages that it is acidic,[6] its action is slower and more difficult to reproduce, and lower yields of desired products are obtained. Other cationic oxidizing agents have been investigated in the presence of nitrites; however, none is effective in yielding *gem* dinitro compounds. Reaction of salts of 2-nitropropane with cupric ammonium hydroxide yields 2,3-dimethyl-2,3-dinitrobutane[7]; with cuprous chloride, cuprous acetate, ammoniacal cuprous chloride, or Fehling solution, the principal product is acetone. Cupric chloride, an acidic reagent, gives propyl pseudonitrole; ferric chloride yields 2,3-dimethyl-2,3-dinitrobutane and ferric 2-propanenitronate. Anionic oxidants such as ammonium persulfate and sodium peroxide oxidize primary[8] and secondary[7] nitronates to *vicinal* dinitro compounds (oxidative dimers) and carbonyl derivatives; neutral potassium permanganate gives the aldehyde[9a] or ketone[9b] as the principal product. Since the effects of silver or mercuric ions seem specific in effecting oxidative nitration of a nitronate, it is possible that introduction of a second nitro group during oxidation–reduction may depend on an intermediate complex salt (Equation 5) whose decomposition into the corresponding dinitro compound is sterically favored.[10]


(5)

A typical procedure for oxidative nitration is illustrated for the preparation of 1,1-dinitroethane. A fresh solution of nitroethane (15.0 g., 0.2 mole), sodium nitrite (4.0 g., 97% assay) and aqueous sodium hydroxide (8.5 g., 80 ml.) was poured into a stirred mixture of aqueous silver nitrate (70.5 g., 0.41 mole in 120 ml.), sodium hydroxide (2–3 drops until silver oxide appeared) and ether (150 ml.) at 0–5°. A cream-colored solid formed immediately and the temperature rose to 10°. The solid decomposed rapidly with blackening and reduction of volume; the temperature rose to 20°. After a few minutes, the cooling bath was removed and the mixture was stirred for 30 minutes. The silver was filtered and washed with ether–benzene. The combined filtrate, on distillation, gave colorless 1,1-dinitroethane (18.9 g., 78%); b.p. 55.5–56° (4.5 min.), $n^{20}{}_D$ 1.4341–1.4346, $d^{20}{}_4$ 1.355, MR_D (calcd.) 22.68, MR_D (found) 23.01, neut. equiv. (calcd.) 120, neut. equiv. (found) 122; lit.[1b] b.p. 55–57° (4 mm.), $n^{25}{}_D$ 1.4322.

---

(6) The desired nitration reaction does not occur in acid solution; the nitrous acid produced reacts with the primary or secondary nitro compounds to yield the corresponding nitrolic acids or pseudonitroles.

(7) See also H. Shechter and R. B. Kaplan, *J. Am. Chem. Soc.*, **75**, 3980 (1953).

(8) A. L. Pagano, Ph.D. Dissertation, The Ohio State University, 1960.

(9) (a) F. T. Williams, Ph.D. Dissertation, The Ohio State University, 1958; (b) S. Nametkin and E. Posdnjakova, *J. Russ. Phys. Chem. Soc.*, **45**, 1420 (1913).

(10) A similar mechanism may be involved in electrolysis of nitronates and nitrite ions at platinum anodes to give *gem* dinitro compounds along with *vicinal* oxidative dimers.[1d] (b) *gem* Dinitro compounds also are formed upon precipitating silver salts of mononitronates in the presence of preformed silver nitrite; *gem* dinitro compounds also are obtained by related processes in the Victor Meyer reaction for preparing mononitro compounds from alkyl halides and silver nitrite. (c) Silver salts of primary nitronates decompose in aqueous suspension to *gem* dinitroalkanes, *vicinal* dinitro compounds, aldehydes, the parent nitroalkane, silver, and nitrous acid, the nitrite generated competes so effectively that *gem* dinitro compounds are the major products formed in such systems.[8]

(11) Organic Chemicals Department, Jackson Laboratories, E. I. du Pont de Nemours and Co., Wilmington, Delaware.

DEPARTMENT OF CHEMISTRY
THE OHIO STATE UNIVERSITY RALPH B. KAPLAN[11]
COLUMBUS 10, OHIO HAROLD SHECHTER

RECEIVED JUNE 14, 1961

A NEW INTRACRYSTALLINE CATALYST

Sir:

An acid (hydrogen) form of synthetic sodium mordenite having high intracrystalline catalytic activity (Table I) has been prepared. Its measured surface area is in the range 400–500 m.²/g. (B.E.T. method). To our knowledge, this is the first complete acid form of an open zeolite (Found: Na, 0.08) with high thermal stability (800°).

The adsorption of only small molecules by other various cation forms of mordenite has been determined by the studies of Barrer.[1] In contrast to their results this new acid form mordenite has adsorption properties intermediate between zeolite "A" and faujasite and catalytic properties similar to zeolite "10X".[2,3,4] Our results are compatible with the crystal structure of mordenite as recently determined by Meier.[5] Preliminary results show that this material is a unique cation exchanger, operating over the entire *p*H range. Exchanges of di and tri-valent cations, such as Mg^{++}, Ba^{++}, Al^{+++} can be accomplished without change in crystal structure from the parent material.

The catalytic cracking properties of the acid mordenite are similar to those described for "10X"[4] including a higher paraffin–olefin ratio than that observed with a silica–alumina catalyst in our experiments.

TABLE I

Cracking of *n*-decane; 1 hr., 450°, L.H.S.V. 0.5

Catalyst	% Conversion	Ratios Isobutane–*n*-butane	Ratios Paraffin–olefin
Acid mordenite	36	1.3	4.6
Silica alumina	19	3.3	3.3

In the 450° temperature range, a somewhat higher catalyst deposit observed with decane cracking over mordenite as compared with that from silica–alumina and silica–magnesia in our work, suggested possible catalytic activity at lower temperatures. Indeed this was observed, when cracking of *n*-hexadecane occurred at temperatures as low as 300°. When *n*-hexadecane was cracked at 350° over acid mordenite and silica–alumina under nearly identical conditions, 6 times more light hydrocarbon (up to C_5) was obtained from the former.

---

(1) R. M. Barrer, *Trans. Faraday Soc.*, **40**, 555 (1944).

(2) D. W. Breck, W. G. Eversole, R. M. Milton, T. B. Reed and T. L. Thomas, *J. Am. Chem. Soc.*, **78**, 5963 (1956).

(3) R. M. Barrer, W. Buser and W. F. Grutter, *Chimia*, **9**, 118 (1955).

(4) P. B. Weisz and V. J. Frilette, *J. Phys. Chem.*, **64**, 382 (1960).

(5) W. M. Meier, private communication.