# NITRATION BY OXIDES OF NITROGEN, PART 3: REACTIONS OF DINITROGEN PENTOXIDE WITH MONO- AND DIOXACYCLOALKANES WITH 5-, 6- & 7-MEMBERED RINGS

P Golding, R W Millar*, N C Paul and D H Richards (deceased)
Ministry of Defence, R.A.R.D.E., Powdermill Lane, Waltham Abbey, Essex EN9 1AX.

Reaction of medium ring cyclic ethers with N_2O_5 in halogenated solvents gave only low yields of the corresponding dinitrates. On the other hand, cyclic formals (1,3-dioxolane and its homologues) gave moderate yields of unstable ring-opened products (hemiformal nitrates), together with variable amounts of rearranged products containing formate ester groups. The formates are believed to result from attack of N_2O_5 on the heterocycle by a hydride abstraction route.

We have reported previously[1] that dinitrogen pentoxide (N_2O_5) cleaves small-ring (3- & 4-membered) oxygen heterocycles, i.e. epoxides and oxetanes, to form the corresponding nitrate ester derivatives (1,2- or 1,3-dinitrates) in high yield. The driving force for the reaction is release of ring strain in the heterocycle, and the ring cleavage proceeds rapidly with simple substrates, that is, those not bearing other ring substituents. We wished to extend the scope of this reaction to other, larger, ring systems, in particular cyclic ethers such as tetrahydrofuran (THF, **1**) and oxepane (**3**), and dioxa-analogues of the 5-, 6- & 7-membered systems (dioxolanes, dioxanes and dioxepanes, as their 1,3-isomers, **4**,**5** & **6**). In addition, some related compounds were

X = CH$_2$, **1**
X = O, **4**

X = CH$_2$, **2**
X = O, **5**

X = CH$_2$, **3**
X = O, **6**
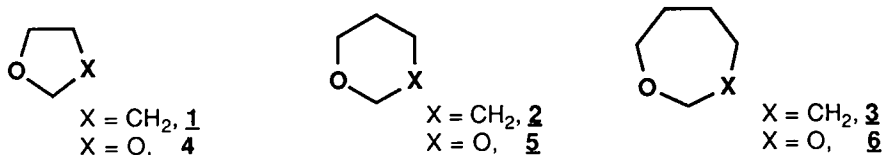
briefly studied – a linear formal, and two 2-substituted 1,3-dioxolanes (see later). Comparisons of conventional ring strain energies (CRSEs)[2] indicated that the cyclic ethers, THF and oxepane, although possessing lower ring strain (CRSEs 23 & 33 kJmol^{-1} respectively) than their small-ring homologues (CRSEs ca 110 kJmol^{-1}), might react similarly to the epoxides and oxetanes, although more sluggishly. The dioxa-analogues were selected for study on account of their ready availability and the possibility of providing a convenient synthesis of the hemiformal nitrate ($-O-CH_2-ONO_2$) group, accessible only with difficulty by known methods[3-5].

We now report that reaction[6] of the cyclic ethers THF and oxepane with N_2O_5 gave only small amounts of the corresponding α,ω-dinitrates (**7** & **8**), detected by hplc[7], after reaction periods of several hours (cf minutes for small-ring compounds), and also they

$$O_2NO-(CH_2)_4-ONO_2 \qquad O_2NO-(CH_2)_6-ONO_2$$

**7**   **8**
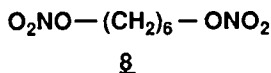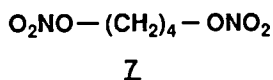
were minor components of complex mixtures which contained predominantly oxidation and/or oligomerisation products (the presence of aldehyde and carboxylic acid products was inferred from the i.r. and nmr spectra of the product mixtures). A brief examination of the reaction of the six-membered homologue (tetrahydropyran, **2**)

indicated that no α,ω-dinitrate was formed, with much unchanged starting material remaining after a multi-day reaction period, in complete accord with the very low ring strain of this substrate. Therefore the reaction of such medium-ring oxygen heterocycles with N_2O_5 does not constitute a useful method for the preparation of α,ω-dinitrates.

Turning to the dioxacycloalkanes, we found that, in the case of the cyclic formals (i.e. formaldehyde acetals) 1,3-dioxolane (4), 1,3-dioxane (5) and 1,3-dioxepane (6), a more rapid reaction took place[6] (essentially complete within several hours) to yield the expected ring cleavage products, namely the hemiformal nitrates 9, 10 & 11[8], but varying amounts of unexpected products resulting from a competing ring cleavage/oxidation reaction, namely the formates 12, 13 & 14[9], were also obtained. The formation of such products, which was most pronounced in the case of 1,3-dioxolane, is believed to involve as the initial step a hydride abstraction by N_2O_5 from the bridging methylene group to give dioxolenium ions of type 15, which rearrange to give the observed products (see Scheme). Hydride abstractions from 1,3-dioxolanes are well known[10] but normally are induced by common Lewis acids (BF_3, trityl salts[11] (e.g.
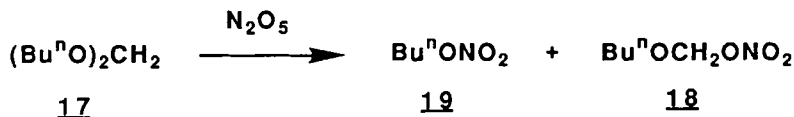

Scheme

$$O_2NO(CH_2)_nOCH_2ONO_2 \qquad O_2NO(CH_2)_nOCHO \qquad O_2NOCH_2OCH_2ONO_2$$
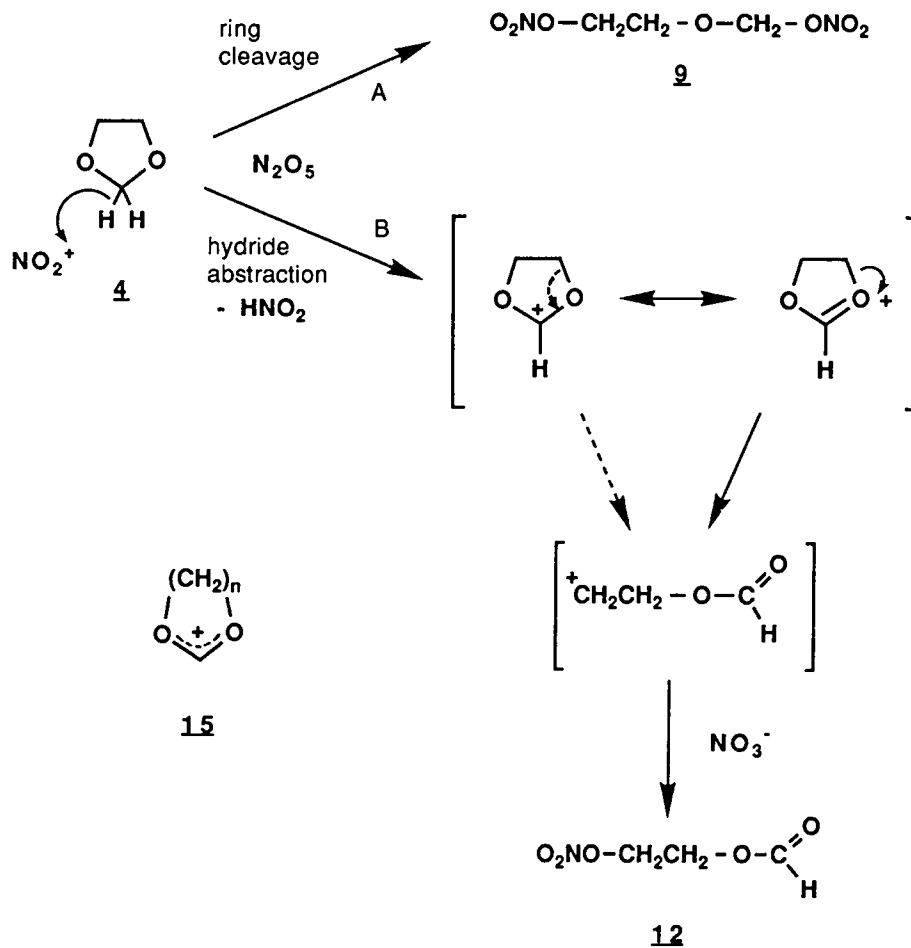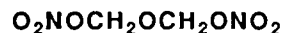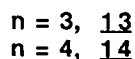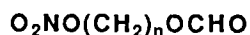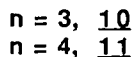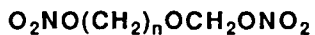
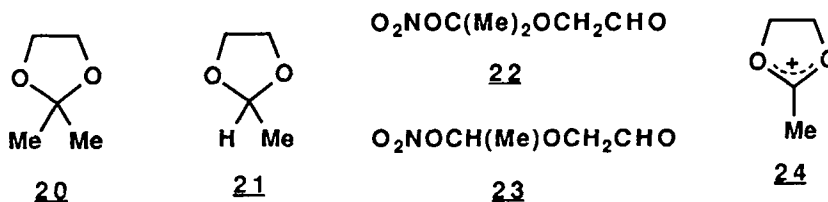| $n = 3,\ \underline{10}$	$n = 3,\ \underline{13}$	
$n = 4,\ \underline{11}$	$n = 4,\ \underline{14}$	$\underline{16}$

$Ph_3C^+BF_4^-$) etc); the reaction reported here is the first case, to our knowledge, of a hydride abstraction induced by N_2O_5. In the case of Lewis acid initiated oligomerisations/polymerisations, generation of formate ester terminal groups from dioxolane is well established[12].

The ratios of the hemiformal nitrate and formate products in the above reactions were also interesting, and correlated with ring size, most formate being obtained with dioxolane and least with the six- and seven-membered homologues (as evinced by ^{1}H nmr integral measurements). This is believed to result from the relative stabilities of the intermediate cations, with the five-membered case, being planar or near-planar, delocalising charge more effectively than the non-planar six- and seven-membered intermediates. It should also be mentioned that the product mixtures which contained a high proportion of hemiformal nitrates were unstable, even after thorough washing to remove traces of acid; this instability is in accord with the reported properties of other compounds of this class (e.g. $\underline{16}$), which are known to deformylate readily[4]. Interestingly, an acyclic formal, di-n-butyl formal ($\underline{17}$), when reacted with N_2O_5 under

$$(Bu^nO)_2CH_2 \quad \xrightarrow{\ N_2O_5\ } \quad Bu^nONO_2 \quad + \quad Bu^nOCH_2ONO_2$$

$\underline{17}$	$\underline{19}$	$\underline{18}$

similar conditions yielded a hemiformal nitrate, $\underline{18}$[13], (together with butyl nitrate ($\underline{19}$) as co-product) but no formate, indicating that the hydride abstraction route makes no contribution in this case, in agreement with the ring size trends noted above.

Finally, the effect of blocking the 2-position of the dioxolane ring was briefly investigated, by examining the reactions of the cyclic ketal, 2,2-dimethyl-1,3-dioxolane ($\underline{20}$) and the corresponding acetal ($\underline{21}$) with N_2O_5. The ketal reacted

$$O_2NOC(Me)_2OCH_2CHO$$
$$\underline{22}$$
$$O_2NOCH(Me)OCH_2CHO$$

$\underline{20}$	$\underline{21}$	$\underline{23}$	$\underline{24}$

Me Me   H Me   Me

sluggishly to produce a variety of products, amongst which was a compound with spectra consistent with an aldehyde-nitrate structure ($\underline{22}$)[14], believed to result from a hydride abstraction at the 4-position of the ring, this alternative position being attacked owing to blockage of the 2-position. Ethylene glycol mono- and dinitrates were also identified (by gc-ftir)[15] as minor products. The acetal, on the other hand, behaved quite differently, with much less aldehydic product, presumed to be $\underline{23}$, being observed; the predominant products were oligomers produced by cationic ring-opening polymerisation via the stable, long-lived dioxolenium intermediate ($\underline{24}$). Such 2-methyldioxolenium salts have been shown elsewhere to be isolable in many cases[10]; moreover, ready oligomerisation of 2-methyldioxolane by strong acids such as $HClO_4$ has been reported[16]. Thus the blocked dioxolanes exhibit chemical behaviour strongly dependent on the degree of substitution on the 2-position, as expected.

References and Notes

1. P Golding, R W Millar N C Paul and D H Richards, *Tetrahed. Letts.*, 29(22), 2731-4 (1988)
2. A R Katritzky "Handbook of Heterocyclic Chemistry", pp 132, 134, Pergamon Press, Oxford, 1985
3. H Bohme and P H Meyer, *Synthesis*, 207-8 (1971)
4. L T Eremenko, A M Korolev, V N Grebennikov and G M Nazin, *Izv. Akad. Nauk. SSSR, Ser. Khim.*, 627-9 (1971); *Chem. Abstr.* 75 48216a
5. G V Oreshko, L B Romanova and L T Eremenko, *Izv. Akad. Nauk. SSSR, Ser. Khim.*, 2140-1 (1973); *Chem. Abstr.* 80 14497f
6. *In a typical run, the oxygen heterocycle (30 mmol) dissolved in CH_2Cl_2 or $CDCl_3$ (15 ml) was added dropwise over 15 min. at -10 to 0°C to a solution of N_2O_5 (35 mmol) in the same solvent (25 ml). The mixture was stirred at 0 to 10°C until the rate of disappearance of starting material had levelled off (monitor by gc or ^1H nmr), typically 16hr, and the mixture was then quenched in saturated $NaHCO_3$ solution, extracted, and the extracts washed well with saturated $NaHCO_3$ solution and water. After drying over anhydrous $MgSO_4$, removal of solvent afforded the product mixture. [Caution: products described herein are energetic compounds and appropriate precautions should be taken in their handling.]*
7. RP18 (Merck) column, methanol-water 60:40 eluant, 30°C, monitor at 210 nm.
8. Yield; ^1H nmr*; [^{13}C nmr*]; i.r.**: 9 - 24% (53% with 150% excess N_2O_5); δ 4.0(m,2); 4.6-4.7(m,2); 5.57(s,2); [δ 66.49 (-CH-O-); 71.09 (O_2NO-CH_2-); 94.30 ($O-CH_2-ONO_2$)], v_{max} 1640, 1283, 856 cm^{-1}; 10 - †; δ 2.08(t,2); 3.88(t,2); 4.59(t,2); 5.55(s,2); v_{max} 1635, 1286, 865 cm^{-1}; 11 - †; δ 1.79(t,4); 3.77(t,2); 4.48(t,2); 5.52(s,2); v_{max} 1631, 1282, 876, 836 cm^{-1}.
9. Yield; ^1H nmr*; [^{13}C nmr*]; i.r.**: 12 - 8% (17% with 150% excess N_2O_5); δ 4.6-4.7(m,2); 8.13(s,1), [δ 59.45 (-CH$_2$-O-); 70.01 (O_2NO-CH_2-); 160.40 (-CHO)], v_{max} 1730, 1640, 1283, 1173, 855 cm^{-1}; 13 - †; δ 2.1(m,2); 4.0-4.4(m,4); 8.20(s,1); v_{max} 1726(m), 1637, 1283, 1157, 866 cm^{-1}; 14 - †; (^1H nmr spectrum not accurately measurable - signals too weak); v_{max} 1723(w), 1631, 1282, 1157(m), 876, 836 cm^{-1}
10. C U Pittman, S P McManus and J W Larsen, *Chem. Rev.(ACS)* 72 357-438 (1972)
11. A Stolarczyk, P Kubisa and S Penczek, *J Macromol. Sci.-Chem.*, 25 627 (1977)
12. S Inoue and T Aida, "Cyclic Ethers" in "Ring Opening Polymerisation", Eds K J Ivin and T Saegusa, Vol. 1, p 196, Elsevier (1984)
13. δ 0.9(m,3); 1.5(m,4); 4.45(t,2); 5.52(s,2); v_{max} 1632, 1282, 874 cm^{-1}
14. v_{max} (gas phase) 1755, 1665, 1281, 1225, 844 cm^{-1}
15. Gc-ftir analyses were performed using an Accuspec Compact II gc and Model 66 I.r. Interface in conjunction with a Nicolet 5SX ftir spectrometer. Chromatograms were run on a 2 m x 3 mm i.d. glass-lined steel column packed with 10% OV101 on Carbosorb.
16. Y Firat and P H Plesch, *J Polym. Sci. Polym. Lett.*, 13 135 (1975)

* All nmr samples were run as CDCl$_3$ solutions. Shifts are reported in ppm downfield from TMS (internal standard).
** All i.r. spectra were recorded as liquid films on KBr plates unless otherwise shown. Absorbances were strong unless otherwise indicated (m/w).
† Product mixtures containing both hemiformal nitrate and formate esters, although obtained in good (50-70%) yields, decomposed within several hr, precluding accurate yield measurements.