A NOTE ON THE BIOLOGICAL ACTIVITY OF THE NOBLE GAS COMPOUND XENON TRIOXIDE*

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Abstract. Xenon trioxide was compared for toxicity in the few common oxidants using three bioassays. On a molar basis XeO_3 and HOCl were similar, but XeO_3 was less active than expected when comparisons were based on normality.

1. Introduction

In spite of their comparative rarity elements of high mass number, such as Au, Hg, Pt, and Ir, can all be found in some form of living matter, at least, between algae and man. Indeed, among the 56 elements in periods 5–7 of the periodic table, only Mo and I of period 5 have recognized biological functions, (vs 23 of the first 37), although over 90% have been found in organisms in nature (Bowen, 1966).

The absence of the heavier noble gases from cells and tissues is even closer to absolute. Thus xenon at 0.086 $\mu g/m^3$ of dry air can be considered one of the small group of elements which living matter has encountered minimally in the course of evolution, and the recently synthesized compounds of xenon would in fact be totally alien to terrestrial biology.

The current toxicology of xenon compounds is limited to oxides, and at present consists only of the report by Finkel *et al.* in 1963 that Na_4XeO_6 is moderately toxic to mammals when given intravenously. Because the barrier properties of organisms must be a vital feature in any natural encounter this early trial is incomplete and inconclusive.

Xenon 'narcosis' is a well-known manifestation of an exotic property in the noble gases and one affecting plants and animals in parallel ways (Bennett, 1966; Buchheit *et al.*, 1966). These effects however require extremely high concentrations, corresponding to ca 500 mm partial pressure.

2. Experimentation and Results

Three biological tests were adopted for exploration and comparative studies: Growth of excised red kidney bean embryos, release of red vacuolar pigments from beetroot tissues, and hatching and survival of brine shrimp.

Embryos were excised from dry seeds and cultured in aqueous solution at pH 6.6, 24 °C. After 3 days, linear and weight increments were measured and corrected for

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initial dry length and weight. Mean length increments and standard errors were based upon 2–3 replicates of 14–20 embryos. Embryos were pooled for fresh weight determination. Brine shrimp data were based upon 3 day cultures in sea water. At least 400 cysts were used per treatment. The beetroot tissue system has been well-characterized previously for the study of membrane-active substances and permeability-regulating conditions (Siegel and Halpern, 1965). The efflux of red pigment was followed by Δ O.D. at 540 nm.

3. Discussion and Conclusions

On the basis of these data, it is obvious that XeO_3 is a powerful growth inhibitor. A comparison with other oxidants does not suggest any consistently unique or distinctive feature in its action. The oxidants selected can be grouped according to oxidation-reduction equivalents per mole as follows:

2	5	6
HOCl		
H_2O_2	$NaIO_3$	XeO_3
Na_2SnO_3		

In general, however HOCl and XeO_3 are comparable inhibitors on a molar basis, hence XeO_3 is less active against growth than HOCl per oxidation-reduction equivalent. Iodate and stannate are also relatively weak inhibitors. In the permeability tests, which are far from complete, XeO_3 seems to be unexpectedly active, as 1.2×10^{-2}N solutions increased leakage far more than did 4×10^{-2}N HOCl.

At 2×10^{-5}M, XeO_3 inhibited elongation of embryos by 58% (Table I). The same, or similar values were found for hypo-chlorite and stannate, but iodate was far less active. Hydrogen peroxide had no significant activity.

At higher concentrations (Table II) HOCl and XeO_3 show increasing and closely parallel inhibitory effect on elongation not manifested with H_2O_2. Growth as reflected in weight increase is somewhat less sensitive than elongation to the oxidants.

When HOCl, XeO_3 and H_2O_2 were compared as growth inhibitors against normality (Figure 1), the peroxide was distinctive for its extreme dependence on equivalent

TABLE I

Comparative inhibition of bean embryo elongation in XeO_3 and four common oxidants

Oxidant (2×10^{-5}M)	Δ Length (72 hr)	
	mm	% Inhibition
Control	3.6 ± 0.2	0
HOCl	1.5 ± 0.2	58
H_2O_2	3.2 ± 0.2	10
$NaIO_3$	2.8 ± 0.2	22
Na_2SnO_3	1.7 ± 0.2	53
XeO_3	1.5 ± 0.1	58

TABLE II

Effects of oxidant concentrations on inhibitory activity toward bean embryos

	Molarity			
	2×10^{-5}	2×10^{-4}	2×10^{-3}	2×10^{-2}
	a. Δ Length (Control $= 3.7 \pm 0.2$ mm)			
HOCl	1.8 ± 0.7	1.5 ± 0.1	1.7 ± 0.2	0.7 ± 0.7
HOOH	3.3 ± 0.2	3.4 ± 0.2	3.3 ± 0.2	3.4 ± 0.2
XeO_3	1.9 ± 0.1	1.4 ± 0.1	0.8 ± 0.1	0.5 ± 0.7
	b. Δ Fr. Wt. (Control = 13.6 mg)			
HOCl	9.5	9.1	7.0	5.2
HOOH	13.5	13.2	11.8	10.6
XeO_3	10.1	5.9	4.6	3.4

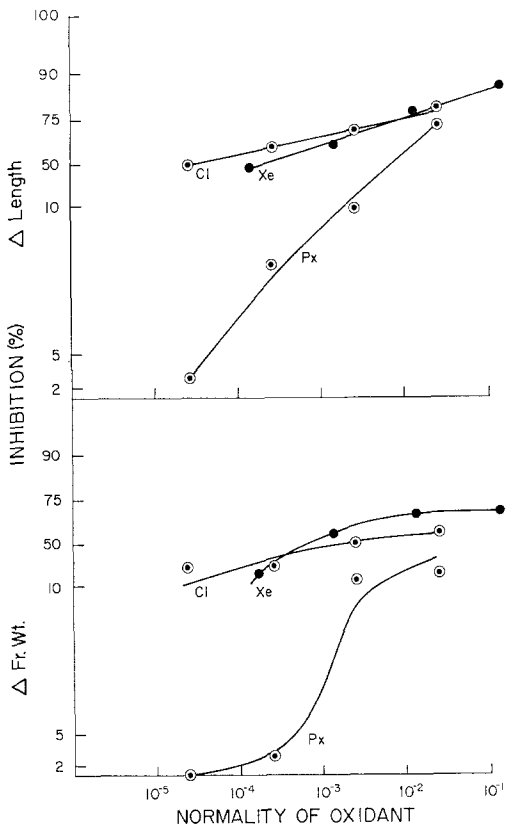

Fig. 1. Effects of increasing concentrations of XeO_3 and other oxidants on growth inhibition in bean embryo. Percentage values are given against normality of Hypochlorite (CL), XeO_3 (Xe) and Hydrogen peroxide (Px).

concentration, but modest differences were still evident between the other oxidants.

Against brine shrimp, (Table III), H_2O_2 was nearly inactive, HOCl and XeO_3were highly toxic and the other oxidants had intermediate activities.

Induction of pigment release from beet root tissues was sensitive to HOCl and XeO_3 within the same concentration range associated with toxicity (Figure 2). Here,

TABLE III

Toxicity of XeO_3 and other oxidants in brine shrimp emergence

	No toxic signs	50% Inhibitions of emergence
	Molarity ($\times 10^{-5}$)	
HOCl	2	5
HOOH	100	$\geqslant 100$
Na_2IO_3	10	> 20
Na_2SnO_3	10	> 20
XeO_3	2	20

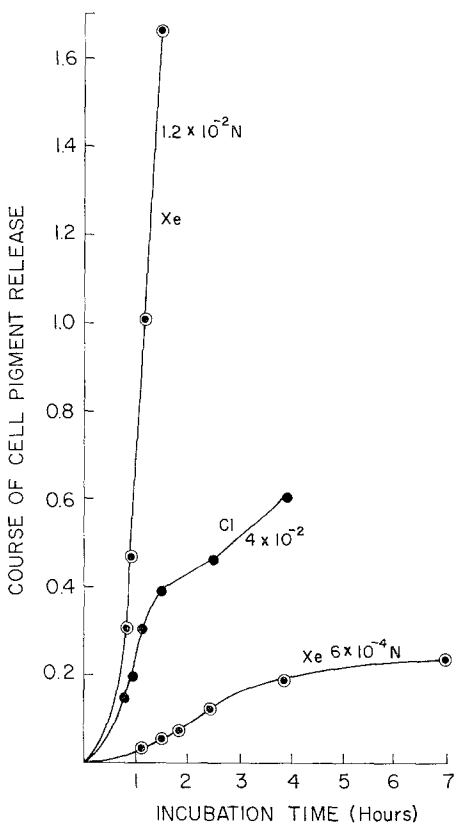

Fig. 2. Beetroot pigment leakage in the presence of HOCl and XeO_3. Data given as optical density at 540 nm vs time.

XeO_3 is far more active than HOCl. Leakage is induced by H_2O_2 only at concentration of ca. 10^{-1}N or more. In the absence of oxidants no leakage occurs over periods of 24 hr or more (Siegel and Halpern, 1965).

The performance of H_2O_2 was as expected in accord with its efficient decomposition by the enzyme.

We conclude therefore that XeO_3 is a biologically active but not unique oxidant and comparatively less active on an equivalent basis than common oxidants such as HOCl. Accordingly exoticism of composition in a molecule does not in itself provide a basis for prediction of mode or extent of biological activity.

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