

OXIDATIVE AND PHOTOOXIDATIVE PHOSPHORYLATION BY  
MEANS OF 1-PHOSPHORYL-1, 4-DIHYDROPYRIDINES

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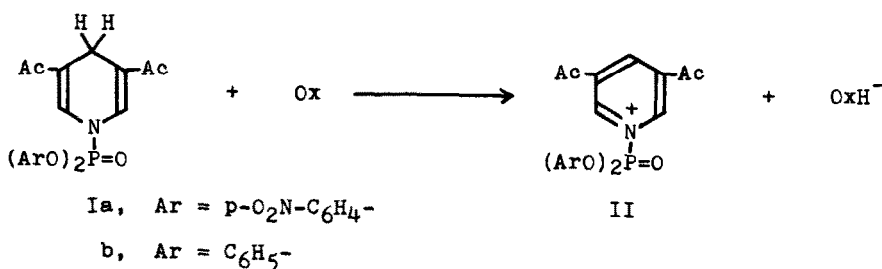
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Oxidative phosphorylation is the mechanism by which the cell utilizes the energy made available by biological oxidations. NAD and NADH play an important role in the process. Some chemical phosphoryl transfer reactions which involve an oxidative step have been suggested as models of biochemical process.<sup>1, 2</sup>

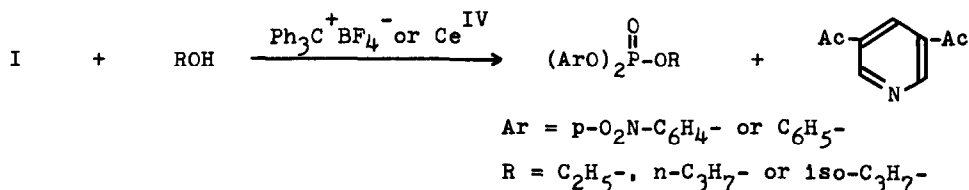
In this paper we wish to report chemical and photochemical oxidative phosphorylation of alcohols by means of 1-phosphoryl-3, 5-diacetyl-1, 4-dihydropyridines (I).

1- Bis(p-nitrophenyl) phosphoryl-3, 5-diacetyl-1, 4-dihydropyridine (Ia; mp 178.5°-179.5°C) and 1-(diphenyl)phosphoryl-3, 5-diacetyl-1, 4-dihydropyridine (Ib; mp 107°-108°C) were prepared by the reaction of sodio 3, 5-diacetyl-1, 4-dihydropyridine with either bis(p-nitrophenyl) or diphenyl phosphorochloridate. If the hydrogen atom at 4-position of the I is abstracted as hydride ion, 1-phosphoryl pyridinium cation (II), a powerful phosphorylating reagent, would be formed.



Since triphenylmethyl cation has been widely used as a dehydrogenating reagent,<sup>3</sup> Ia (487 mg, 1 mmol) was treated with triphenylmethyl fluoroborate (395 mg, 1.02 mmol) in acetonitrile (20 ml) under reflux for 2 min, cooled to room temperature, and then ethanol (4.60 g) was added. After the solution was kept stirring for 4.5 hr, ethyl bis(p-nitrophenyl) phosphate was isolated in a 43% yield; mp 137°C (from ethanol). When the reaction was carried out in the absence of triphenylmethyl fluoroborate, Ia was quantitatively recovered.

Clark, et al., have reported that monobenzoate of hydroquinone in ethanol was oxidized by ceric ion to give ethyl benzoate.<sup>4</sup> Trahanovsky, et al., and Rocěk, et al., in a recent detailed investigation of ceric ammonium nitrate oxidation of cycloheptatriene have demonstrated the formation of a tropylium ion intermediate.<sup>5, 6</sup> Treatment of Ia with 6 molar equivalents of ceric ammonium nitrate in ethanol at room temperature for 5 days afforded ethyl bis(p-nitrophenyl) phosphate in a 72% yield. When Ib was allowed to react with 4 molar equivalents of ceric ammonium nitrate in ethanol at room temperature for 2 days, ethyl diphenyl phosphate was isolated in an 85% yield. Similarly, propyl and isopropyl diphenyl phosphates were obtained in 87% and 81% yields, respectively.<sup>7</sup>



In a preceding paper, we describe that 1, 4-dihydropyridines are successfully photooxidized to corresponding pyridines under certain conditions.<sup>8</sup> The photosynthetic phosphorylation process is considered to be an important component reaction of the over-all process of photosynthesis. Thus, as a simple chemical model, we next investigated photochemical phosphoryl transfer by the use of Ib.

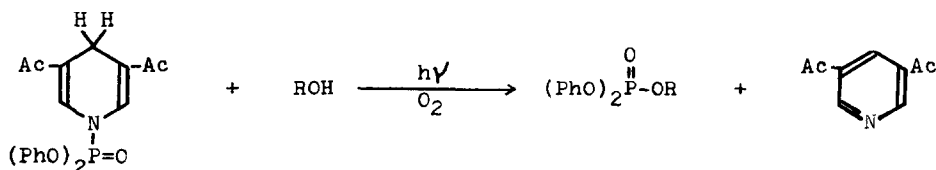
When Ib (1 mmol) in ethanol (75 ml) was irradiated under an atmosphere of oxygen with super high pressure mercury lamp with filter for about 3.5 hr,<sup>9</sup> ethyl diphenyl phosphate and 3, 5-diacetylpyridine were isolated by preparative

Table 1. Photooxidative Phosphorylation of Alcohols by Means of 1-(Diphenyl)phosphoryl-3, 5-diacetyl-1, 4-dihydropyridine (Oxygen Atmosphere at Room Temperature)

ROH	Reaction Time		Product		
			$(\text{PhO})_2\overset{\text{O}}{\parallel}\text{P}-\text{OR}$		3, 5-Diacetyl pyridine
R	hr	min	R	%	%
$\text{C}_2\text{H}_5-$	3	42	$\text{C}_2\text{H}_5-$	67(23)*	53(15)*
$n-\text{C}_3\text{H}_7-$	7	30	$n-\text{C}_3\text{H}_7-$	57	29
$\text{iso}-\text{C}_3\text{H}_7-$	10	10	$\text{iso}-\text{C}_3\text{H}_7-$	53	27
$n-\text{C}_4\text{H}_9-$	7	20	$n-\text{C}_4\text{H}_9-$	57	33
$\text{sec}-\text{C}_4\text{H}_9-$	8	40	$\text{sec}-\text{C}_4\text{H}_9-$	42	24
$\text{tert}-\text{C}_4\text{H}_9-$	9		$\text{tert}-\text{C}_4\text{H}_9-$	0	12

\* (); Irradiation was carried out under nitrogen atmosphere for 14 hr.

tlc in 67% and 53% yields, respectively. On the other hand when the irradiation was carried out under nitrogen atmosphere for 14 hr, only a 23% yield of ethyl diphenyl phosphate was isolated. This result shows that oxygen may act as hydrogen acceptor. Similarly, various alcohols were successfully photophosphorylated as shown in Table 1. Under a separate experiment, it was proved that Ib was stable at least for periods of 2 days in ethanol at room temperature.



In the case of phosphorylation of tert-butanol, no tert-butyl diphenyl phosphate could be detected presumably due to unstability of the product.<sup>10</sup>

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\* To whom correspondence should be addressed.

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