Electrochemical Oxidation of Hydrazones
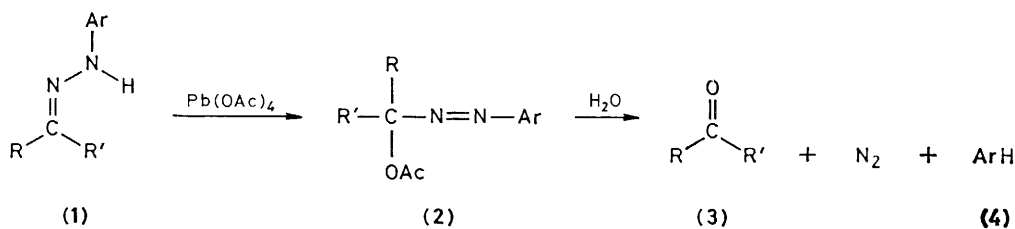
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Anodic oxidation of keto-arylhydrazones produced the parent ketone while a cyclic hydrazone yielded a rearranged product.

Recent reports on the synthetic utility of hydrazones[1] and their oxidation by lead tetra-acetate to a large variety of synthetic intermediates[2] prompted us to investigate the mechanism and possible synthetic applications of the anodic oxidation of simple hydrazone derivatives. The lead tetra-acetate oxidation of keto-hydrazones has been well studied.[2] The

Scheme 1

Table 1. Oxidation of ketone 2,4-dinitrophenylhydrazones.

R	R'	F mol^{-1}	i/A	(3)	(4)	$E_p^{1/2d}$
Bu^t	Bu^t	2	0.25	59	45	1.072
Me	Ph	4^e	0.2	99	87	0.997
Me	Me[CH$_2$]$_6$	2	0.2	65		1.068
Me^b	Ph	2	0.2	76		0.997
[CH$_2$]$_5$		2	0.2	40		1.052
[CH$_2$]$_5$^{b}		2	0.2	65		1.052
[CH$_2$]$_4$		2	0.2	41		1.082
[CH$_2$]$_4$^{b}		4	0.2	82		1.082

with column headers grouped: **(1)**^{a} covers R, R', F mol^{-1}, i/A; **% Yield** ^{c} covers (3), (4).

^{a}2,4-Dinitrophenylhydrazone (1) in 200 ml H$_2$O–MeCN (20:80) containing 2 g of LiClO$_4$ at 25 °C. ^{b}As footnote (a), but with MeCN–H$_2$O 90:10 as solvent. ^{c}Remainder of material where 1,3-dinitrobenzene (4) was isolated was starting hydrazone to a material balance of >90%. ^{d}Potential taken from cyclic voltammetry at 5 mV/s sweep rate vs. Ag/0.1 M AgNO$_3$ reference electrode. ^{e}As footnote (a) but at 50 °C.

formation and isolation of the azo-compound (2) (Scheme 1) has been noted by many workers and proceeds in 50—80% yield.[3] Saponification of this azo-ester yields the parent ketone and the aromatic compound (4), liberating nitrogen. The electrochemical oxidation was envisioned to proceed in an analogous manner.

Simple aliphatic 2,4-dinitrophenylhydrazones were electrochemically oxidized at a graphite anode with a platinum or graphite cathode in 200 ml of 20% water–80% acetonitrile containing 2 g of lithium perchlorate and 1—10 g of the hydrazone. The ketone was produced in yields (unoptimised) of 40—99%. Table 1 summarizes these results. It was found that the anolyte must be separated from the catholyte to

prevent reduction of the arylhydrazone. This separation may readily be accomplished with a sintered glass frit or use of a dialysis (cellulose) bag around the cathode. All preparative electrolyses were performed with a constant current power supply with applied voltages never exceeding 20 V.

The ratio of the ketone to 1,3-dinitrobenzene was very similar to that of the lead tetra-acetate oxidation suggesting a similar pathway. Increasing the amount of current passed increased the ketone yield only slightly. However, owing to the low solubility of the hydrazones in the media, increasing the temperature or decreasing the water content to 10% increased the ketone yield dramatically. If water was rigorously excluded, the reaction mixture turned dark and intractable. The proposed mechanism for the overall reaction is shown in Scheme 2. We obtained similar results for p-nitrophenyl-, p-chlorophenyl-, and phenyl-hydrazones.

Cyclic voltammetry was used to determine the oxidation potentials of the substituted acetophenone 2,4-dinitrophenyl-hydrazones and their structural dependence. The results correlated with the Okamoto Brown[4] σ^+ values which support the mechanism shown in Scheme 2. All the substituted aceto-phenone 2,4-dinitrophenylhydrazones showed an irreversible 2-electron wave with no reverse reduction wave even at sweep rates of 500 V/s. As the data in Table 2 indicate, there is a perfect correlation between $E_p^{1/2}$ and σ^+ indicating a positive charge build-up in the rate limiting step. However, further confirmation of the decomposition step was necessary.

For this we chose a cyclic hydrazone (5) which would be capable of intramolecular trapping of any carbanion formed in the decomposition step. The proposed mechanism is depicted in Scheme 3. The intramolecular rearrangement is very similar to the Favorskii rearrangement which involves formation of a cyclopropane ring followed by ring opening.[5] When
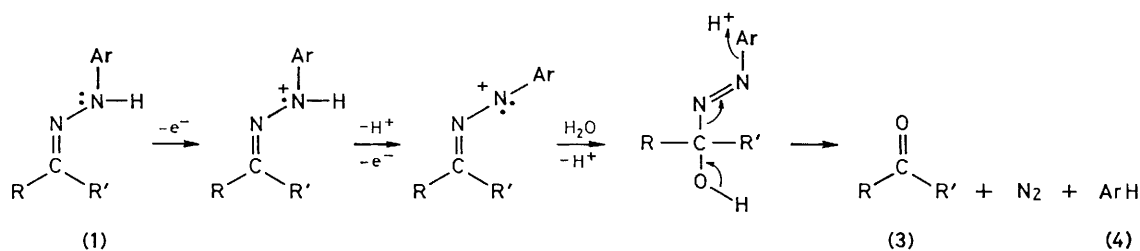
Scheme 2
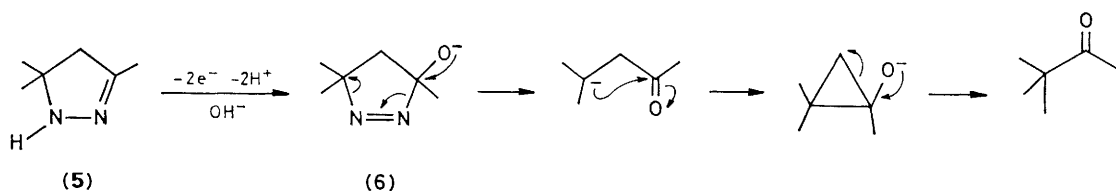
Scheme 3

Table 2. Cyclic voltammetry data for X-substituted acetophenone 2,4-dinitrophenylhydrazones.[a]

X	$E_p^{1/2}$ [b]	σ^+ [c]
H	0.997	0.000
p-Me	0.948	−0.311
p-OMe	0.873	−0.778
p-Cl	1.015	+0.114
p-NO$_2$	1.123	+0.790
m-NO$_2$	1.102	+0.674

[a] Correlation R = 1.000, slope (ρ) = 0.159, intercept 0.997 mV. [b] Half-peak potential at a 5 mV/s sweep rate *vs.* a Ag/0.1 M AgNO$_3$ reference electrode. [c] Ref. 4.

the anodic oxidation of (5) was performed in neutral media as before, or under acidic conditions, only 4-methylpentan-2-one was detected; however, with the addition of 1 equiv. of pyridine the yield of 3,3-dimethylbutan-2-one was 26% with the remainder being starting material. This low yield can readily be explained by the current being used to oxidize the hydroxide ion. The formation of both 4-methylpentan-2-one and 3,3-dimethylbutan-2-one further supports the proposed mechanism. Diazenes similar to intermediate (6) have been the topic of many recent papers owing to their thermal decomposition to produce unique bicyclic structures.[6] Thus, the ionic decomposition may prove synthetically useful.

This work illustrates the potential utility of anodic oxidation as a method for the 'hydrolysis' of hydrazones of ketones. It should be noted that the potentials required for this reaction can be quite low which makes it compatible with most common functional groups.

References

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