

ON THE ELECTROCHEMICAL BEHAVIOUR OF NICOTINAMIDE

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Most of the biological interest in pyridine derivatives centres around nicotinamide which is the building block for the coenzymes, Nicotinamide adenine dinucleotide (NAD). Except for some polarographic studies, not many references are available on the electrochemical behaviour of nicotinamide. In the present investigation, the reduction of nicotinamide has been studied in non aqueous medium using glassy carbon electrode, in the solvent dimethyl formamide (DMF). Investigations have been carried out in the potential range + 400 mV to -2400 mV at different scan rates using tetra alkyl ammonium perchlorates as the supporting electrolyte. Two cathodic peaks are observed around -1.6 V and -1.9 V. Depending upon the alkyl group used in the supporting electrolyte, the peak potentials are slightly varied. A small broad oxidation peak was observed on the reverse scan. From the value of peak currents, the value of n was determined to be one for each peak. Nicotinamide was found to get reduced in the ring yielding 1,4-di hydronicotinamide.

Keywords: Nicotinamide, cyclic voltammetry and coulometry.

INTRODUCTION

Nicotinamide belongs to the family of pyridines. Pyridines are six membered ring compounds containing a single heterocyclic nitrogen and a double bond system analogous to that of benzene. Not many references are available on the electrochemical behaviour of nicotinamide (NA) Reported literature in connection with the electrochemistry of nicotinamide consists mainly of polarographic data. The reason could be that nicotinamide gets reduced at a potential in aqueous media very near to that of background discharge reaction on solid electrodes. As it is possible to have long range of negative potential on mercury electrode in aqueous medium itself, the investigations have been mostly confined to polarography [1-5]. From the available literature it is learnt that nicotinamide gets reduced in two steps as shown by two polarographic waves, each involving one electron transfer. A catalytic wave at further negative potentials has also been reported [6-8]. The only detailed study regarding the electrochemistry of NA in aqueous medium is that by Elving *et al.* [6] According to them in acidic medium, two adjacent waves each involving one electron transfer and a catalytic has been reported. At alkaline pH the presence of a highly

reversible couple corresponding to wave 1 process has been identified. The reduction product was identified as 1,4 dihydro nicotinamide. Later investigations by R.M.Galvinand J.M.R.Mellado [9-13] indicate a different mechanism. At acidic pH, NA yields 3-Pyridine Carbinol as the product and pH 6.0 NA undergoes reduction in the ring yielding 1,4 dihydro nicotinamide [12].

Only one report is available on the electrochemistry of NA in non aqueous medium. Santhanam and Elving [14] have shown that NA gets reduced in two steps each involving one electron transfer and the mechanism is similar to that observed in alkaline pH. In the present investigation the studies have been made in non aqueous medium with a view to study the mechanism of reduction in detail on glassy carbon (GC) electrode.

EXPERIMENTAL

AR chemicals have been used for the investigation. DMF has been purified by distillation before use. The solutions were deaerated for an hour using nitrogen before the experiments. Cyclic voltammograms were recorded using Wenking Potentiostan (POS 73) and Rikadenki X-Y/t recorder using GC (BAS, MF 2012) as the working electrode,

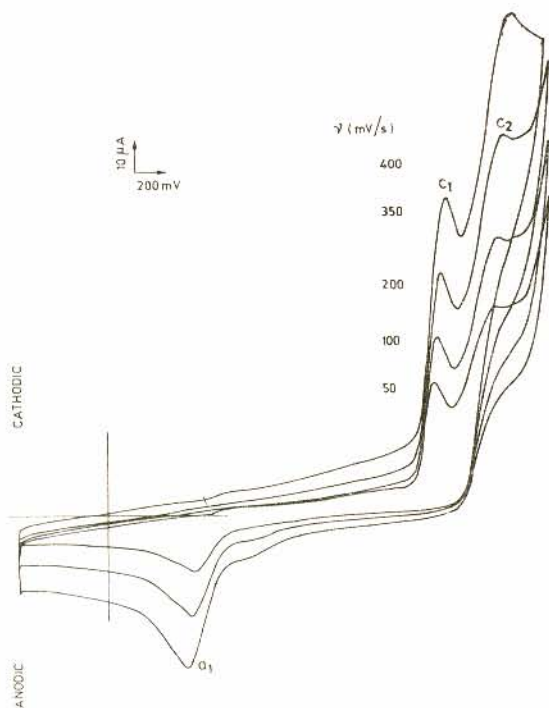


Fig. 1: Typical cyclic voltammograms of Nicotinamide (8 mM) in the medium DMF/TMAP

Pt foil as the counter electrode and Ag⁺/AgCl as the reference electrode. Coulometric experiments were carried out using a GC rod of area 3.76 cm².

RESULTS AND DISCUSSION

Fig. 1 shows the typical cyclic voltammograms of NA in the medium DMF/TMAP (tetra methyl ammonium perchlorate). Two well defined cathodic peaks are observed on the cathodic side at -2.11 V and -2.35 V. The peaks show a shift in the potential with scan rate (Table I). When the potential

TABLE I: Peak potentials, peak currents for Nicotinamide in DMF/TMAP

Medium	Concn mM	ν mV/s	E_{pc1} V	E_{pc2} V	i_{pc1} μA	i_{pc2} μA	E_{pa1} mV	i_{pa} μA
DMF/ TMAP	8.0	50	-2.08	-2.36	45	45	-560	28
		100	-2.10	-2.40	60	75	-540	38
		200	-2.13	-2.44	85	88	-500	48
	16.0	400	-2.15	-2.48	120	130	-470	60
		50	-2.11	-2.35	72	65	-550	22
		100	-2.13	-2.38	100	88	-530	38
16.0	200	-2.16	-2.44	140	120	-500	65	
	400	-2.22	-2.50	180	170	-460	90	

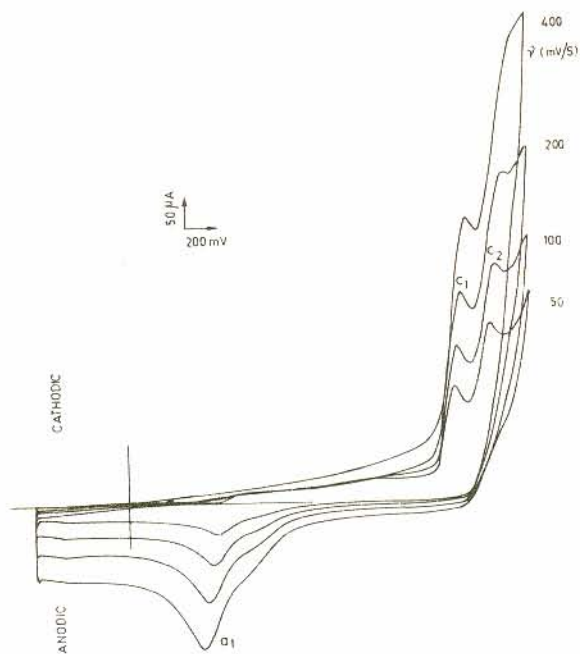


Fig. 2: Typical cyclic voltammograms of Nicotinamide (8 mM) in the medium DMF/TEAP

range is restricted upto peak C₁, the anodic peak A₁ also appears with a decreased peak current.

Fig. 2 shows the typical cyclic voltammograms of NA in the medium DMF/TEAP (Tetra ethyl ammonium perchlorate). The observations are similar as in the above case. However, the peak C₁ and C₂ occurs at more negative potentials like -2.12 V and -2.56 V in this medium (Table II).

Fig. 3 represents the typical cyclic voltammograms of NA in the medium DMF/TBAI (Tetra butyl ammonium iodide). The observations are again almost similar to that of the

TABLE II: Peak potentials, peak currents for Nicotinamide in DMF/TEAP

Sl No	Concn mM	ν mV/s	E_{pc1} V	E_{pc2} V	i_{pc1} μA	i_{pc2} μA	E_{pa1} mV	i_{pa1} μA
1.	8.0	50	-2.14	-2.52	40	42	-580	13
		100	-2.16	-2.54	59	60	-560	24
		200	-2.18	-2.58	75	75	-520	33
2.	16.0	400	-2.22	-2.16	110	130	-500	45
		50	-2.12	-2.56	72	56	-500	22
		100	-2.15	-2.60	98	70	-480	38
16.0	16.0	200	-2.20	-2.66	130	88	-430	56
		400	-2.75	-2.74	160	—	-380	80

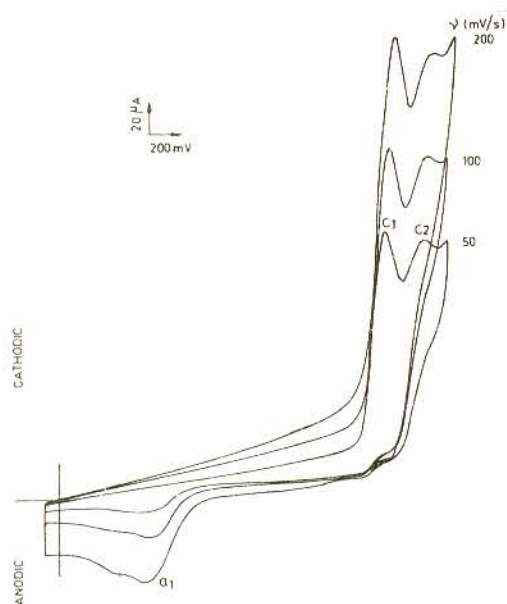


Fig. 3: Typical cyclic voltammograms of Nicotinamide (8 mM) in the medium DMF/TBAI

medium DMF/TMAP. In this medium, the peak C_1 and C_2 occur at a potential of -2.14 V and -2.6 V (Table III).

From the results presented so far it is clear that NA gives two adjacent well defined cathodic peaks separated by about 0.2 V to 0.5 V. The general behaviour does not seem to be affected significantly by change in supporting electrolyte. The potential of peak C_1 in presence of iodide ions is slightly higher than in perchlorate. The peak potential of C_2 occurs almost at the same potential in all the cases. A small oxidation peak A_1 occurs in all the cases in the reverse scan. The fact that the peak A_1 can be seen even when the potential scan range is restricted up to peak C_1 and C_2 . The peak C_1 and C_2 are found to be irreversible according to the diagnostic criteria.

TABLE III: Peak potentials, peak currents for Nicotinamide in DMF/TBAI

Sl No	Concn M	v mV/s	E_{pc1} V	E_{pc2} V	i_{pc1} μ A	i_{pc2} μ A	E_{pA1} mV	i_{pA1} μ A
1.	8.0	50	-2.12	-2.36	72	14	-660	7
		100	-2.16	-2.38	92	17	-620	5
		200	-2.18	-2.42	115	18	-580	26
2.	16.0	50	-2.14	-2.60	105	23	-640	15
		100	-2.18	-2.62	138	23	-600	30
		200	-2.22	-2.66	185	23	-540	50
		400	-2.28	-2.68	195	23	-500	70

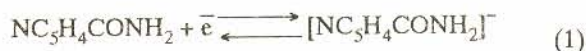
The value of n is calculated for the peak C_1 from the peak current values in the medium DMF/TMAP using the current expression for irreversible electron transfer.

$$i_p = 3 \times 10^5 n \alpha n_a^{1/2} A v^{1/2} C D^{1/2}$$

n is found to be one for peak 1. The first step may correspond to the formation of a radical intermediate as suggested by Elving *et al.* In aqueous medium the 2 electron reduction of nicotinamide often occurs as a single wave or as a overlapping of two waves. However in non aqueous medium and by using the technique of differential pulse polarography, the 2 electron reduction could be separated into two separate well defined peaks. By carrying out the reduction in non aqueous medium, the radical intermediate could be stabilised by forming complex with tetra alkyl ion and hence two well separated peaks could be observed.

By controlled potential electrolysis at -2.5 V in the medium DMF/TMAP and subjecting the electrolysed sample to UV spectral analysis, it was found that 1,4 dihydro nicotinamide is the product of reduction, which is similar to that observed in alkaline medium. Based on the above facts a tentative mechanism is suggested for the reduction (Fig. 4).

According to literature reports, it is proposed that the radical intermediate formed in the first step undergoes dimerisation according to equation 2. The radical then undergoes further reduction to 1,4 nicotinamide. However in non aqueous medium the radical is stabilised by ion pair formation with tetra alkyl salts. So reaction 3 occurs without the occurrence of step 2.



Nicotinamide



Dihydro Nicotinamide

Fig. 4: Reaction mechanism

CONCLUSIONS

From the forgoing discussions it is clear that NA gets reduced in two steps as represented by two well separated peaks. In aqueous medium, overlapping waves or very closely overlapping waves were obtained whereas in non aqueous medium, the two one electron transfer steps are well separated. In non aqueous medium, the radical intermediate is stabilised to some extent by complexation with tetra alkyl cation. Hence dimerisation of radical is not observed. 1,4 dihydro nicotinamide is proposed to be the reduction product as evidenced by UV spectral analysis.

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