

COMPARATIVE STUDIES FOR 2-PROPANOL ELECTROOXIDATION ON PLATINUM AND NICKEL ELECTRODES IN ALKALINE MEDIA

Mircea Laurentiu Dan, Delia Andrada Duca, Nicolae Vaszilcsin, Nicoleta Maria Dragomir

*University Politehnica Timișoara, Faculty of Industrial Chemistry and Environmental Engineering, 300223, Parvan 6, Timisoara, Romania
e-mail: d_nicoleta16@yahoo.com*

Abstract

In this paper, new aspects of 2-propanol oxidation electrocatalytic effect on platinum and nickel electrodes, in aqueous alkaline solution was investigated using voltammetric studies. 2-propanol oxidation reaction has been studied by cyclic and linear voltammetry.

Introduction

Small alcohols electrooxidation from C1 - C3 group has been intensely studied, mainly because of their possible use in fuel cells [1]. Methanol, although extensively used, is toxic inflammable with low boiling point and is not a primary fuel. Ethanol isn't toxic and can easily be obtained from sugar and biomass [1,2]. The use of alcohols with longer chains for applications in fuel cells can also be attractive considering the high energy content emitted in fuel [3]. 2-propanol is the smallest secondary alcohol and far less toxic than methanol. Its electrochemical oxidation has aroused great interest due to its particular molecular structure [4,5]. Alcohols with more than two carbon atoms in their structure have several isomers and special features of non-CO adsorption [6]. When the onset potentials for oxidation of different alcohols were compared, the performance of 2-propanol was superior as against of methanol and ethanol [7]. The possibility to use 2-propanol as electrolyte in direct alcohols fuel cells (DAFCs) has been reported since 1995 [8].

Platinum has been extensively investigated as electrocatalyst for 2-propanol electrooxidation in both acid and alkaline electrolytes. Pt is easily poisoned by the reaction intermediates [9]. Also, platinum high price and limited supply constitute a major barrier for DAFCs development, other materials with similar catalytic properties being necessary [4,10]. Nickel is a good electrocatalyst for methanol and ethanol oxidation in alkaline electrolyte. However, there is little information on the electrocatalytic properties of 2-propanol oxidation on nickel in alkaline medium.

In this paper, comparative studies for 2-propanol electrooxidation on platinum and nickel electrodes in alkaline media are presented using different electrochemical methods, such as: cyclic voltammetry, linear polarization and chronoamperometry.

Experimental

Electrochemical tests were performed at room temperature using a SP-150 potentiostat/galvanostat (Bio-Logic, SAS, France). A 100 mL typical glass cell was equipped with three electrodes: Pt/Ni working electrodes, Ag/AgCl reference electrode and two graphite rods used counter electrodes. For performed experiments, the exposed surface of working electrode was 0.5 cm². Different concentrations of 2-propanol were added: 0.125, 0.25, 0.5, 0.75 and 1 mol L⁻¹ in 1 mol L⁻¹ KOH, all prepared from Sigma-Aldrich reagent p.a. min 99.8%.

Results and discussion

Cyclic voltammograms recorded on platinum electrode, between -1.5 and +2.0 V/Ag/AgCl, at 50 mV s^{-1} scan rate, in 1 mol L^{-1} KOH with different 2-propanol concentration, are depicted in Figure 1, starting from open circuit potential (OCP). Potential domain associated with 2-propanol oxidation on platinum electrode is between +0.7 and +1.8 V.

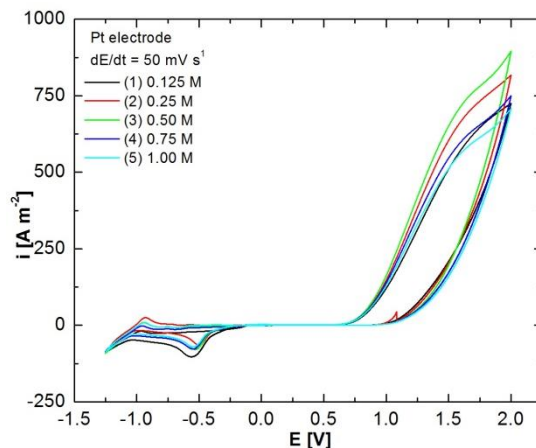


Figure 1. Cyclic voltammograms plotted on platinum electrode in 1 mol L^{-1} KOH with different concentration of 2-propanol, scan rate: 50 mVs^{-1} .

In order to study the electrochemical processes occurring at platinum electrode surface in 1 mol L^{-1} KOH with 0.75 mol L^{-1} 2-propanol, cyclic voltammograms (3 cycles) were recorded, starting from OCP, in the potential range between -1.00 and +0.60V, at 50 mVs^{-1} scan rate, when current density is small, few A m^{-2} . Platinum oxides formation/dissolution on electrode surface and oxidation/reduction of different intermediate products formed in 2-propanol electrooxidation were followed.

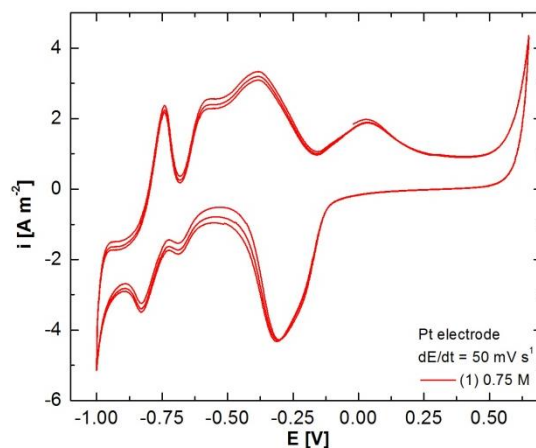


Figure 2. Cyclic voltammograms plotted on platinum electrode in 1 mol L^{-1} KOH with 0.75 mol L^{-1} 2-propanol, scan rate: 50 mVs^{-1} .

Similarly, in figure 2 are presented cyclic curves plotted in 1 mol L^{-1} KOH with different concentration of 2-propanol, on nickel electrode, between -1.4 and +0.6 V/Ag/AgCl potential range, at 50 mV s^{-1} scan rate. Potential domain characteristic for 2-propanol electrooxidation is between +0.4 and +0.6 V, depending on the alcohol concentration added in electrolyte solution.

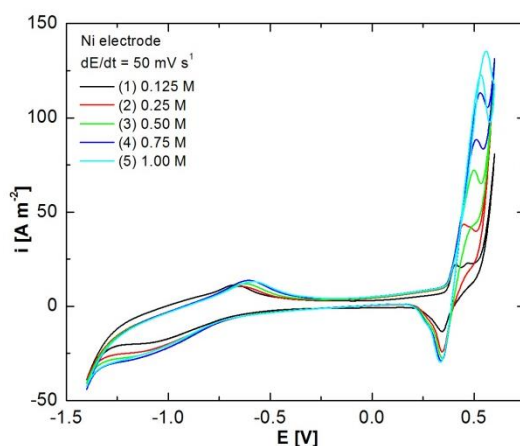


Figure 3. Cyclic voltammograms plotted on nickel electrode in 1 mol L⁻¹ KOH solutions with different concentration of 2-propanol, scan rate: 50 mVs⁻¹.

Linear voltammograms plotted at low scan rate (1 mV s⁻¹) in 1 mol L⁻¹ KOH + 0.75 mol L⁻¹ 2-propanol, on both platinum and nickelelectrodes are shown in figure 4 a and b. The curves shape indicates only one oxidation process on electrode surface.

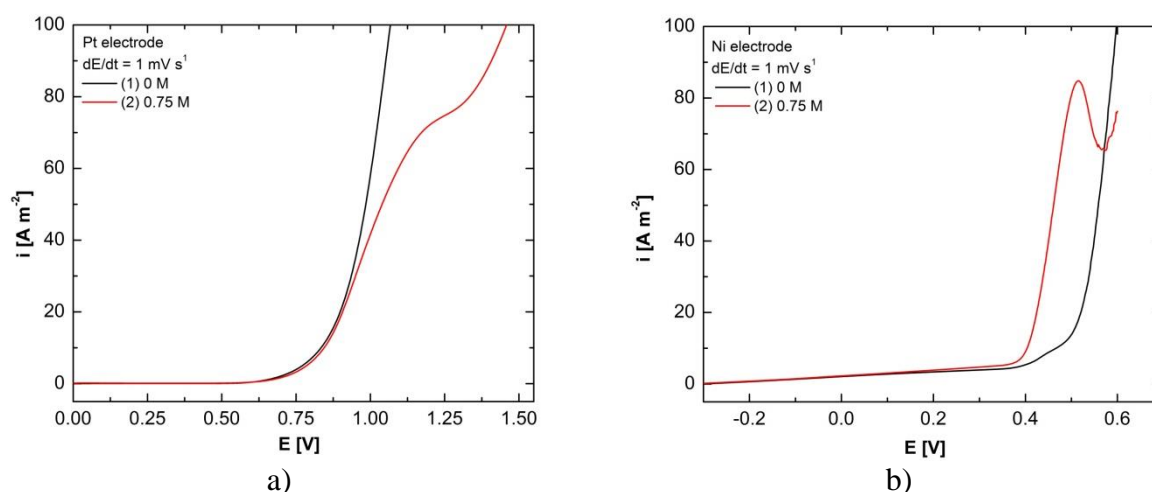


Figure 4. Linear voltammograms plotted on platinum (a) and nickel (b) electrode in 1 mol L⁻¹ KOH + 0.75 mol L⁻¹ 2-propanol, scan rate: 1 mV s⁻¹.

On metallic electrode, especially platinum, 2-propanol electrooxidation in alkaline medium can be described by following reactions [4]:



The overall reaction is:



S.G. Sun and Y. Lin demonstrated that equation (1) is a fast reaction, and acetone oxidized into CO₂ is a relatively slow reaction [12].

Chronoamperometric measurements had as starting point the linear voltammograms shown in figure 4 a and b. Analyzing these curves, three potential values were chosen for the 2-propanol electrooxidation in alkaline solution on each electrode:

(1) $E = +1.00$ V, (2) $E = +1.25$ V and (3) $E = +1.50$ V for platinum electrode;

(1) $E = +0.40$ V, (2) $E = +0.45$ V and (3) $E = +0.50$ V for nickel electrode.

All potentials values are given versus the reference electrode ($E_{\text{ref}} = 0.197 \text{ V}$ vs NHE). Chronoamperometric studies were performed for 60 minutes. Graphical results are presented in figure 5 a and b. Also, chronoamperometric comparative data recorded on both platinum and nickel electrodes, in alkaline electrolyte without and with 0.75 mol L^{-1} 2-propanol are presented. Anodic oxidation of 2-propanol at different potential values are inserted in figures.

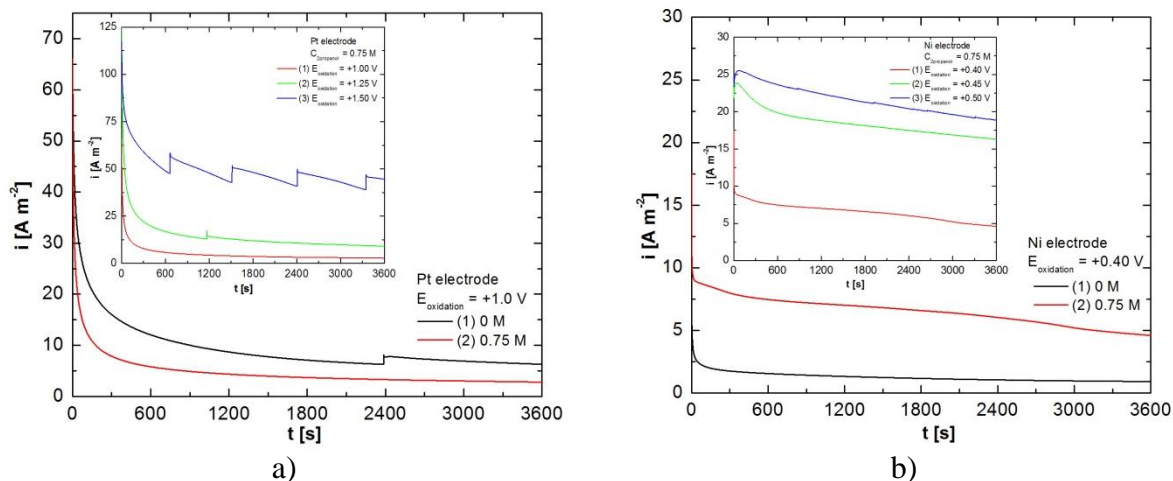


Figure 5. Chronoamperometric studies on platinum (a) and nickel (b) electrode 1 mol L^{-1} KOH in the absence and presence of 0.75 mol L^{-1} 2-propanol.

Analyzing graphical data recorded on platinum electrode can conclude that at +1.00 and +1.25 V potential values, the only process occurring at the interface is 2-propanol oxidation. If chronoamperometric measurements are carried out at +1.50 V, the curve shape indicates oxygen evolution reaction on electrode surface.

Conclusion

In this study, platinum and nickel electrodes have been tested for 2-propanol electrooxidation reaction. Cyclic voltammetry, linear polarization and chronoamperometry used as electrochemical analysis techniques confirm an increased activity for studied process in alkaline solution.

Acknowledgements

This work was partially supported by University Politehnica Timisoara in the frame of PhD studies.

References

- [1] M. S. Ureta-Zanartu, C. Berríos, T. Gonzalez, F. Fernandez, D. Baez, R. Salazar, C. Gutierrez, *Int. J. Electrochem. Sci.*, 7 (2012) 8905.
- [2] F. Maillard, F. Gloaguen, F. Hahn, J. M. Leger, *Fuel Cells*, 2 (2002) 143.
- [3] S. S. Gupta, J. Datta, *J. Chem. Sci.* 117(4) (2005) 337.
- [4] J. Ye, J. Liu, C. Xu, S. P. Jiang, Y. Tong, *Electrochem. Commun.* 9 (2007) 2760.
- [5] P.T.A. Sumodjo, E.J. Silva, T. Rabochai, *J. Electroanal. Chem.* 271 (1989) 305.
- [6] H. B. Hassan, *TOELECJ* 1 (2009) 19.
- [7] S.LJ. Gojkovic, A.V. Tripkovic, R.M. Stevanovic, *J. Serb. Chem. Soc.* 72(12) (2007) 1419.
- [8] J.T. Wang, S. Wasmus, R.F. Savinell, *J. Electrochem. Soc.* 142 (1995) 4218.
- [9] C.G. Lee, M. Umeda, I. Uchida, *J. Power Sources* 160 (2006) 78.
- [10] M.E.P. Markiewicz, D.M. Hebert, S.H. Bergens, *J. Power Sources* 161 (2006) 761.
- [11] S.G. Sun, Y. Lin, *J. Electroanal. Chem.* 375 (1994) 401.