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Summary: The cyclic voltammetric electrochemical technique was utilized to investigate the effect of different temperatures on the redox current peaks of rifampicin (RF), a drug commonly used to treat many diseases including tuberculosis (TB), in vitro for human blood medium. A modified working electrode of glassy carbon electrode (GCE) with carbon nanotube (CNT) (CNT / GCE) was used as a sensitive nano-sensor to evaluate the impact of temperature on the blood medium in the presence of RF ions.

The results confirmed the presence of two oxidation and one reduction current peaks of RF in blood medium at 0.5, 1, and -0.5 V respectively. The redox current peaks of RF ions in blood medium were enhanced with increasing the temperature from 20 to 36°C. The activation energy (E*) values were determined by applying Arrhenius equation with oxidative and anti-oxidative peaks of Ea*(1pa)= 9.252 and 11.026 kJ.mol-1.K-1,respectively. Other thermodynamic functions such as the change in each of activation Enthalpy (ΔH*), activation Gibbs energy (ΔG*) and activation Entropy (ΔS*) values were estimated using Eyring equation. The present results of the effects of different temperatures on the blood status in presence of RF lead to the explanation of the oxidative stress of the drug which used in an inflammatory of blood at different temperature.

Keywords: Rifampicin; Cyclic voltammetry technique; Blood medium; Nano-sensor; Different temperature.

Introduction

A number of recent studies have investigated the influence of medicines in blood medium to identify the potential oxidative stress of commonly used drugs on patients. Such proposed effects have been assessed by electrochemical analysis utilizing cyclic voltammetric technique with nano-sensors [1-6].

Rifampicin (RF) is one of the first line treatments of tuberculosis (TB) disease. Its chemical structure is 3-(4-methyl-1-piperazinyl) [7]. It is important to study this drug by techniques such as cyclic voltammetry (CV), differential voltammetry (DPV) and steady state amperometry under aerobic conditions. Nanobiosensor could be adapted to study the electrochemical properties of such drug. This is of importance since it would help to increase our understanding to the therapeutic mechanisms and bimolecular interaction of the drug of interest. It was found that 0.025 - 14 μM covers the peak of rifampicin serum level value of 0.045 μM [8]. Hepatic drug-metabolizing enzymes were found to be inducted by Rifampicin, and these enzymes increase the metabolism of many drugs making them ineffective. This highlights the significant of drug interactions which could help in tackling the threat of several diseases and improving the quality of life.. High-performance liquid chromatography (HPLC) is also utilized as a simplified measurement of rifampicin concentrations in blood [9 ]. Along with that, cyclic voltammetry is a commonly used approach to study the effect of thermal exposure on the electrochemical properties of environmental pollutants, such as Pb(II) ions, by in vitro assessing the redox current peaks in human blood medium [10]. A lead deposition reaction in different temperature ranges of 25 to 75 °C was studied on substrates of Pb, Cu, Ag, and C using linear and cyclic sweep perturbation in lead chloride and ammonium acetate. Adsorption isotherms, Tafel slopes, and diffusion coefficient were determined as a consequence of the increasing temperature [11]. Electrochemical analysis of the tuberculosis (TB) disease’s drug by oxidation and flow injection analysis [12]. Another study of rifampicin study in high detection limit was studied [13] and rifampicin study in high detection limit was studied [14].

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In this study a sensitive working electrode CNT/GCE was used in the determination of thermodynamic properties of Rifampicin drug in blood medium.

**Experimental**

**Reagents and Chemicals**

Rifampicin was purchased from Ajanta pharma limited (India), carbon nanotubes (purity 99%) were supplied by Fluka company (Germany), and normal saline from AdwicPharmaceuticals Division (Egypt). Healthy human blood samples were obtained from the Iraqi Blood Bank in Baghdad Medical City, Baghdad-Iraq.

**Instruments**

"nuvant systems inc., pioneering electrochemical technologies, USA, was adapted in this study for the assessment of the Rifampicin electrochemical properties in vitro using EZstat series (potentiostat/glvanostat) device".

For the output of the Cyclic Voltammogram test, electrochemical workstations of the Bioanalytical Integral System are connected to personal computers with potetiostat operated by electroanalytical software. In addition to using Ag / AgCl (3 M KCl) to calculate the reference signal while using Platinum wire (1 mm diameter) as counter electrode.

**Preparation of modified GCE with CNT (CNT/GCE)**

"The CNT / GCE working electrode was prepared using a modified mechanical attachment technique, which was then used to set up the nano-sensor [15,16]. The modification of GCE included abrasive application of carbon nanotubes (CNT) on the clean surface of GCE. This forms an array of CNT used as a modified CNT / GCE working electrode and put in the cyclic voltammetric cell of 10 ml of the diluted blood with a normal saline ratio of (1:9). The potentiostate was then connected to all electrodes (working electrode, reference electrode and counter electrode)".

**Control of temperature**

The temperature was controlled by using water bath, in which the cyclic voltammetric cell was placed, the gradual heating was done using a controlled heater, and the temperature was measured using a mercury thermometer.

**Results and Discussion**

**Enhancement of redox current peaks using CNT/GCE**

In this work a modified working electrode GCE with CNT (CNT/GCE) was used as a sensitive nano-sensor to determine the electrochemical properties of redox current peaks of Rifampicin(RF) in blood medium at different temperature (20–36°C). Fig. 1 shows the cyclic voltammogram of RF exposed to different temperature. The cyclic voltammogram of RF showed two oxidation current peaks at 0.5 and 1V. Also, one of reduction current peaks at -0.5 V enhanced the redox current peaks by increasing temperature. This suggests a catalyst effect of the temperature changes [17].

![Fig. 1: Rifampicin cyclic voltammogram on modified working electrode (CNT / GCE) at different temperatures in the blood medium](image-url)

**Effect different temperatures on the blood medium redox current of RF**

The potential effect of temperature change on blood composition was investigated in the present study. This was performed utilizing Cyclic voltammetric technique in the presence of RF compound by tracking the values of redox current peaks using electrochemical analysis. The results showed that blood medium incubated with RF be affected when it is exposed to increase the temperature degree, rising cell device prone to heat (20-36 C°). This effect was displayed as a change in the redox current peaks as demonstrated in Fig. 1.

Observing the apparent results, it was found that the peaks of the two oxidation current was at 0.5 and 1 V, with one of the reduction current peak at -0.5 V being enhanced upon decreasing the temperature.
The activation energy (E*) value

The influence of different temperature degrees on the redox reaction of RF in blood medium was investigated in this study by testing the reduction current peak patterns of the RF compound.

Activation energy was determined using Arrhenius equations (1) and (2) [18, 19]

\[ \sigma = \sigma_0 \exp \left( -\frac{E^*}{RT} \right) \]  
(1)

\[ D = D_0 \exp \left( -\frac{E^*}{RT} \right) \]  
(2)

where \( \sigma / D \) refer to conductivity / diffusibility while \( \sigma_0 / D_0 \) represent standard conductivity / the initial diffusibility.

The chemical reaction rate at absolute temperature T (in kelvins) was estimated (quantified) using the equation of Arrhenius from the value of the rate constant k dependence. For this equation, A represents the pre-exponential factor (or simply the pre-factor), whereas E* refers to the activation energy and the symbol R to the universal gas constant:

\[ k = A \exp \left( -\frac{E^*}{RT} \right) \]  
(3)

\[ \log(Ip) = \log A - \frac{E^*}{2.303RT} \]  
(4)

The slope linear line relation \(-E^*/2.303R\) was calculated by plotting \log(Ip) against 1/T.

"In the above equation: k is the rate constant that replaced with Ip, which refers to the current peak of the oxidation or reduction produced by the electrochemical reaction".

The relationship between \ln(Ipa), \ln(Ipc) and 1/T are shown in Figs 2 and 3. It was found from the slope of the straight line that the activation energy of oxidation-reduction of RF have values of 9.031 and 11.024 KJ/mol K, respectively.

Fig. 2: Relationship between \ln(Ipa) against to inverse temperature of the oxidation current peak of RF in blood medium at different temperature using CNT/GCE and Ag/AgCl at SR=100mVs\(^{-1}\).

Fig. 3: Relationship between \ln(Ipc) against to inverse temperature of the reduction current peak of RF in blood medium at different temperature using CNT/GCE and Ag/AgCl at SR=100mVs\(^{-1}\).
The negative value of free energy according to the law Gibbs-Helmholtz free energy, the spontaneous reaction of redox Rifampicin process in mentioned equations 3, 4, and 5. The results showed that constant $k = \frac{RT \ln (k h / T k)}{m^2}$ using Erying equation medium.

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Thermodynamic functions ($\Delta H^*, \Delta G^*, \Delta S^*$) of Rifampicin in blood medium

The activation free energy ($G^*$), enthalpy ($H^*$) and entropy ($S^*$) of Rifampicin in blood medium values on the modified electrode CNT/GCE were determined using Erying equation and thermodynamic equations [19]:

\[
\Delta G^* = -RT \ln (k h / T k_b) \quad (3)
\]

Erying equation

\[
\Delta H^* = \Delta G^* + T \Delta S^* \quad (4)
\]

\[
\Delta H^* = \Delta G^* + T \Delta S^* \quad (5)
\]

"where gas constant $R = 8.314 \text{ Jmol}^{-1} \text{K}^{-1}$, Boltzmann constant $k_b = 1.381 \times 10^{-23} \text{ m}^2 \text{kg sec}^{-1} \text{K}^{-1}$, and Planck constant $h = 6.66 \times 10^{-34} \text{J sec}$, with multiplier of temperature T (K)."

The thermodynamic functions of Rifampicin in blood medium were determined from the above mentioned equations 3, 4, and 5. The results showed that the spontaneous reaction of redox Rifampicin process in blood medium at different temperature was done according to the law Gibbs-Helmholtz free energy, not only depend on change in enthalpy ($\Delta H^*$) (Table-1). This redox process is becoming spontaneous when the value of free energy ($\Delta G^*$) is negative and enthalpy change ($\Delta H^*$) is negative too which can be seen in the reversible reaction of cathodic current peak, but entropy ($\Delta S^*$) is showed to have a positive value [20] as it is illustrated in table 1. Moreover, the nanoparticles (CNT) act as a catalyst for redox reaction of rifampicin in blood medium especially the anodic process [21].

Conclusion

In this work the effect different temperature on the redox process of Rifampicin compound in blood medium using nano-sensor (CNT/GCE) was analyzed by cyclic voltammetric method to identify the thermodynamic functions such as activation energy ($E_a^*$), activation free energy ($G^*$), enthalpy ($H^*$) and entropy ($S^*$) using Arhenius equations and Erying equation. It was found from the results that Rifampicin compound has the process of redox current peaks in blood medium as a spontaneous reduction action which is indicated by the negative values of both free energy ($\Delta G^*$) and enthalpy change ($\Delta H^*$), but nonspontaneous of oxidation reaction. The study’s results also suggested a key role for the nano-sensor (CNT/GCE) in the diffused ions in the cyclic voltammetry in blood medium.

References


