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Alcian Blue-Modified Carbon Paste Electrode for Cyclic Voltammetric Detection of Salbutamol Sulphate

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ABSTRACT

This research presents the development and characterization of an Alcian blue (AB)-modified carbon paste electrode (ABMCPE) for the electrochemical detection of salbutamol sulfate (SBS) using cyclic voltammetry in a phosphate buffer solution at pH 7.2. The study highlights the significant improvement in electrochemical behavior and sensitivity for SBS detection when utilizing ABMCPE compared to a bare carbon paste electrode (CPE). Cyclic voltammetry demonstrated that SBS undergoes irreversible oxidation at 611 mV on bare CPE, whereas the ABMCPE exhibited enhanced peak currents and introduced secondary oxidation peaks at neutral pH due to the presence of AB as an electron mediator. The electrochemical characteristics, including the effects of pH and scan rate, were systematically analyzed, revealing a diffusion-controlled mechanism for SBS oxidation on the ABMCPE. The method exhibited a low detection limit confirming the electrode's applicability in pharmaceutical formulations. Notably, the ABMCPE successfully quantified SBS in commercial asthma tablets, demonstrating its potential for practical biosensor applications. This study underscores the advantages of ABMCPEs, including enhanced sensitivity, straightforward preparation, and cost-effectiveness, positioning them as valuable tools for drug monitoring and detection in clinical settings.

Keywords:-Alcian Blue (AB),Modified Carbon Paste Electrode (MCPE), Cyclic Voltammetry (CV), Salbutamol Sulphate (SBS), Phosphate Buffer Solution (PBS), Electrode Fabrication, Limit of Detection(LOD), Limit of Quantification (LOQ), Electrochemical Sensitivity Tablet Sample Analysis, Bronchodilator, P2-Adrenergic Agonist, Chronic Obstructive Pulmonary Disease (COPD).

INTRODUCTION

Alcian blue (AB) and bare carbon paste were manually mixed to make an AB chemically modified carbon paste electrode. Salbutamol sulphate (SBS) in phosphate buffer solution was studied using cyclic voltammetry (PBS, pH 7.2). (CV). Cyclic voltammetry showed that SBS oxidation at bare CPE caused a noticeable oxidation peak. Secondary oxidation occurs at and below pH 9.0.

Alcian blue modified carbon paste electrode (ABMCPE) secondary oxidation occurred at neutral pH. (7.2). Alcian blue modified carbon paste electrodes (ABMCPEs) had higher main and secondary peak currents than bare carbon paste electrodes (CPE). pH and scan rate were tested on the bare and ABMCPE to see how they interacted. ABMCPE found that the LOD and LOQ are both 9 x 10'* M. LOD is three times lower than LOQ. The approach found for SBS in the sample of tablets for sale. Due to its high sensitivity, low detection limit, and easy manufacture, the electrode may be used in future sensors. Biosensors may also utilize this.

Salbutamol sulfate (l-(4-hydroxy-3-hydroxyphenyl)-2-tert-butyl amino ethanol) is a heart-friendly bronchodilator. Scheme 5.1 contains Salbutamol sulfate. Short-acting P2-receptor agonist albuteroli treats bronchospasm in asthma and COPD patients. This helps patients breathe. Salbutamol became the first commercially available selective P2-receptor agonist in 1968. Salbutamol sulfate pills directly affect the bronchial smooth muscle, making them popular. Salbutamol's full impact may take five to twenty minutes, but some alleviation may be felt almost immediately. It may also be breathed, swallowed, or injected intravenously. Salbutamol, or albuterol, is a P2-receptor-selective bronchodilator. The medicine is offered as a racemic mixture because the R isomer activates metabolic pathways and the S isomer blocks them.

Asthma, bronchospasm, and COPD patients typically get salbutamol (COPD). It eases breathing by relaxing the airways and lungs. SBS prevents asthma and treats reversible bronchospasm in children and adults via mouth or inhalation. SBS's unique p2-adrenergic agonism treats asthma. SBS, a tocolytic used to treat humans and animals, may still affect people via its leftovers in meat and liver. The SBS treats humans and animals. SBS in tablet form increased quadriceps femoris and hamstring strength over time. In obstetrics, the drug treats nasal congestion and delays labor to start at the right moment. Many prefer salbutamol over clenbuterol for performance and fat reduction. In competitive sports, urine salbutamol levels above 1000 fig/L are considered abusive.

Most people experience fine tremor, anxiety, headaches, muscular cramps, parched mouth, and palpitations. Medication may induce these symptoms. Low blood pressure, fainting, behavioral and sleep issues, and collapse are further symptoms. Sleep problems may occur. It's concerning that high doses of xanthine derivatives, diuretics, or all three may cause hypokalemia. Because to this, SBS detection is crucial, and numerous methods have been developed to do it.

SBS in pharmaceutical formulations may be detected via spectrophotometry, thin-layer liquid chromatography, high-performance liquid chromatography, gas chromatography, mass spectrometry, fluorometry, and capillary electrophoresis. Pretreatment of the sample is crucial for the activities, which are complicated, time-consuming, and expensive owing to equipment. Electrochemical procedures are simpler, faster, and cheaper than others. Salbutamol was oxidized using differential pulse voUammetry at a glassy carbon electrode measured voltammetrically at a platinum and gold ultra-micro electrode, Fourier-transform cyclic voltammetry, and irreversible bioamperometry with flow injection. They oxidized salbutamol.

Throughout the previous several years, altered electrodes have shown to boost electrochemical determination sensitivity. SBS detection using modified electrodes such fullerene-Ceo-modified glassy carbon electrodes and salbutamol plastic membrane composite electrodes based on solo and combination ion-exchangers has also been studied for decades. This study employed numerous modified electrodes, including fullerene-Ceo-modified glassy carbon electrodes.

Alcian blue (AB) and other phthalocyanines may be used to determine SBS, however this is unproven. Transition metal complexes as electron mediators may replace electrochemical analysis to discover physiologically relevant chemicals. This increases voltammetric response sensitivity. Metallic phthalocyanines are used as catalysts in many redox processes due to their flexibility, high catalytic activity, and inexpensive cost. Water completely decomposes alcian blue, cationic copper (II) phthalocyanine. AB has been used to electrocatalytically oxidize nitrite and detect dopamine.

SBS measurement using a carbon paste electrode has received little attention in the literature. This supports survey results. Nafion-modified CPE with fenoterol and metaproterenol, which are chemically related, may detect SBS. These molecules are similar. Cyclic voltammetry was used to study SBS electrochemical oxidation. AB-modified cationic CPE was the experimental media. ABMCPE's assessment of SBS in a commercial tablet sample shows the electroanalytical technique's accuracy without pretreatment. The sample was tested for SBS.

MATERIAL AND METHODOLOGY

Experimental Reagents and Chemicals:-

SBS was brought from Sigma-Aldrich (Mumbai, India). AB was obtained from Allied Industries and G.S. Chemical Testing Laboratory. Since each of these chemicals were of analytical grade, no further purification was needed before usage. 0.05M sodium hydroxide was added to 0.1M KH_2PO_4-prepared phosphate buffer solution (PBS) to get the desired results. Spectroscopically pure graphite powder was obtained from LobaChemie. Water was distilled twice for every solution. SBS stock solution was made before measuring.

Preparation of the Alcian Blue Modified Carbon Paste Electrode:-

ABMCPE was made by stirring bare carbon paste with Alcian Blue dye at various concentrations. Their values were 1–8 mg. Following that, the adjusted carbon paste was applied to the electrode using the same procedure. Before measuring, the electrode surface was polished using translucent paper to provide a steady, homogenous, and undisturbed surface.

RESULTS AND DISCUSSION

1. Electrochemical behavior of SBS at bare CPE:-

SBS's cyclic voltametric behavior was measured at a bare carbon paste electrode (CPE) in PBS at 100 mV/s in the potential range of -1300 to 1300 mV. The PBS solution was preserved at pH 7.2, and the potential range was -200 to 1300 mV. SBS irreversibly oxidized at 611 mV when exposed to bare CPE. The scan rate and solution pH were studied to understand the electrochemical process at bare CPE.

With 3.2 x 10" M SBS, a significant and irreversible primary oxidation peak was found at every pH from 2 to 10. At pH 9.0, the oxidation peak potential flipped from positive to negative, revealing a new secondary mechanism. pH rose at the same time. Oxidation of the phenolic hydroxyl group—either acidic or basic—starts the process. The subsequent step is undetectable in acidic settings because the hydroxyl group connected to the benzene alkyl group was likely oxidized.

The CPE has better resolving power for electrode processes at comparable potentials since a glassy carbon electrode did not cause this process. Note this. This is crucial, so remember it. Lower pH values indicate a minor reduction peak generated by oxidation at a larger negative potential. Perhaps oxidation byproducts generated this decrease peak. Oxidation may have caused this visual change. The optimum pH for further research is 7.2, which is close to the physiological pH.

In PBS with 7.2 pH, scan rate was analyzed and commented. The scan rate increases the oxidation peak current.

The peak potential is unaffected by scan speed, which may vary from 50 to 400 mV/s, suggesting a diffusion-regulated mechanism at the bare CPE.

The SBS's cyclic voltammetric response was tested for modifier concentration. AB concentrations from 1 mg to 8 mg were analyzed to discover how much they affected salbutamol sulfate oxidation. PBS included salbutamol at 3.2 x 10" M and 100 mV/s. PBS was also scanned at 100 mV/s. Saturation was 4 mg at both the greatest and lowest responses.Despite increasing AB concentration, the peak current remained almost same for the duration of the trial. Peak potential decreased between peaks pi and pa, indicating the modifier transported an electron swiftly. So, to continue the study, 4 mg AB was selected as the most effective modifier concentration to increase electron transit.

SEM Characterization of AB-modified carbon paste electrode:-
The bare CPE was covered with flaky graphite ranging in size from a few micrometers to a few hundred micrometers and having an irregular shape. SBS molecules were uniformly placed on the modified electrode. AB particle surfaces did not behave this way.

Stability of AB-modified CPE:-
It's observed that the anodic current reduction in AB-treated carbon paste using a series of potential scan numbers to assess its stability. ABMCPE SBS anodic peak current decreased. More scans reduced ABMCPE's electrochemical activity.

Electrochemical activity may decrease due to the dissolution of the AB cation generated at the electrode into the aqueous solution. Each experiment involved replacing the ABMCPE surface. The RSD for 10 duplicate measurements using an AB carbon paste electrode holding 4 mg was 2.45% under ideal conditions. As AB-modified carbon paste may be made rapidly, the electrode doesn't need to be stored.

Electrochemical study of SBS at AB-modified CPE:-
AB is an oxidizing agent that may convert the hydroxyl group linked to the alkyl group of a benzene ring into an aldehyde. The aldehyde group converts the hydroxyl group. The oxidation peak currents of peaks p and p2 doubled compared to the bare CPE, suggesting the scan rate was steadily altering. Despite the present increase, the peak potential remained constant, suggesting the scan rate was progressively altering. Unlike this hypothetical time span, alcian blue blank concentration does not peak.

Effect of SBS concentration and detection limit:-
Using cyclic voltammetry at 100 mV/s, the influence of salbutamol concentration on anodic peak currents was examined to establish the detection limit and linear range for salbutamol in PBS (pH 7.2). This determined the salbutamol detection limit and linear range in PBS (pH 7.2). This experiment determined the salbutamol detection limit and linear range which defines the detection limit.It was observed that the values for the LOD and LOQ were, respectively, 6 x 10-5 M and 2 x l0 "M. Its detection limit for SBS measurement using different electrodes was much higher than that of other researchers (Table-1), and five calibration curves yielded comparable statistical findings. The LOD and LOQ formulae were: LOD is three standard deviations per slope and LOQ is one slope per standard deviation where S is the standard deviation and M is the slope (sensitivity) generated using calibration curves with an n-of-5 sample size.

The solution contained more than 1.8 xl0 SBS "M, a third oxidation peak appeared at 900 mV. Hence, the second peak entered a negative potential. The carbon paste electrode may oxidize an already-oxidized substance.

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Pharmaceutical preparation: Determination of SBS in tablets:-

SBS was identified in commercial asthalin-4 tablets to validate the recommended technique (the stated amount of each tablet was reported as 4 mg on the sample). The weight of the 10 pills, each containing 4 mg of salbutamol sulphate, was obtained by averaging the results. Once the tablets were crushed and weighed, they were mixed with deionized water and poured into a 100-milliliter volumetric flask.

To dissolve the salbutamol, the liquid was sonicated for 20–30 minutes. After filtering out insoluble components, the liquid was washed and diluted with PBS to the desired concentration. Filtering the mixture removed any insoluble components (pH 7.2). The experimental procedure just reviewed was used to quantitatively analyze SBS while fine-tuning the experimental conditions for optimal results.

Table-2 shows SBS cyclic voltammetric results in commercial tablets. The voltammogram, used to determine how much SBS was in the commercial pill, shows two peaks.

After mixing the SBS standard solution with the sample solution, the recovery test was done. This preceded the exam. Table-3 shows the examination results: The technique used to quantitatively measure SBS in pharmaceutical formulations was successful.

CONCLUSION

Salbutamol Sulphate (SBS) was electrochemically characterized on unmodified and Alcian Blue (AB)-modified carbon-paste electrodes (CPEs). It was carried out on Cyclic voltammetry in 0.1 M phosphate buffer solution. Cyclic voltammetry showed that SBS irreversibly oxidized on bare CPE, resulting in a single peak. Second oxidation was seen at pH 9.0.

1. Adding AB to the CPE allowed the secondary procedure to be performed at pH 7.2 with improved sensitivity. This was better than leaving the CPE unaltered.
2. pH and scan rate affected unmodified and ABMCPE, and cyclic voltammetry showed that SBS oxidation on alcian blue-modified CPE was diffusion-controlled at lower scan rates.
3. With a detection limit of 6 x 10-5 M, the anodic peak current (Ipai) and SBS concentration are linearly related in the range of 48 x 10-4 M to 0.16 x 10-4 M. This relationship was found between 48 and 0.16 x 10-4 M.
4. The strategy uses cyclic voltammetry to measure SBS content in actual samples (tablets).
5. The Alcian Blue-modified CPE can test SBS in pharmaceutical formulations which can be manufactured easily and cheaply.

Table-1: Comparison between the detection limits of the proposed method with the other previously reported methods:-

Substrate	pH	Linear range (M)	Detection limit(M)
Glassy carbon electrode	5.0	$8x10^{-7}$ to $8x10^{-5}$	2 $xl0^{-7}$
Platinum electrode	6.0	$1x10^{-4}$ to $1x10^{-3}$	8 x 10^{-5}
Glassy carbon electrode	6.0	$2x10^{-5}$ to1 $x10^{-3}$	1 x 10^{-5}
Polyaminosulfonic acid-modified glassy carbon electrode (PASA GC)	6.8	2 x 10^{-6} to 1 x 10^{-3}	6.5 x $l0^{-7}$
Nano gold particles modified indium tin oxide (NGITO)	7.4	50 $x10^{-9}$ to 250 x 10^{-9}	7.5 x 10^{-8}
AB-modified carbon paste electrode	7.2	$1.6x10^{-6}$ to $0.48x10^{-5}$	$6x10^{-8}$

Table-2: Determination results of Salbutamol Sulphate IP in commercial tablets

Sample no.	Specified(mg) (n=5)	Detected (mg)	RSD%
1	4.0	3.901	2.01
2	4.0	3.925	1.97
3	4.0	4.001	1.85
4	4.0	3.935	2.2
5	4.0	3.87	2.36

Table-3: The recovery test (n=3)

Sample no.	SBS sample concentration (mg)	Standard SBS added (mg)	Total found (mg)	Recovery (%)
1	4.0	1.0	4.93	98.6
2	4.0	2.0	5.87	97.83
3	4.0	3.0	7.06	100.85
4	4.0	4.0	7.98	99.75
5	4.0	5.0	9.1	101.11

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