ELECTROCHEMICAL AND SPECTROSCOPIC CHARACTERIZATION OF IRON-NICKEL OXIDE NANOPARTICLE AS A HIGH-PERFORMANCE ELECTRODE MODIFIER FOR DOPAMINE DETECTION

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INTRODUCTION

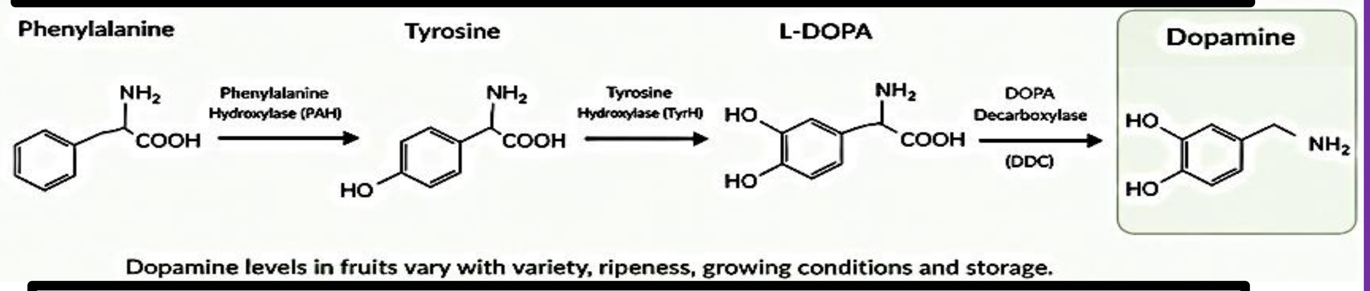
Definition and description

✓ **Dopamine** is a neurotransmitter belonging to the class of organic chemical compounds known **as catecholamine neurotransmitters** [1,2].

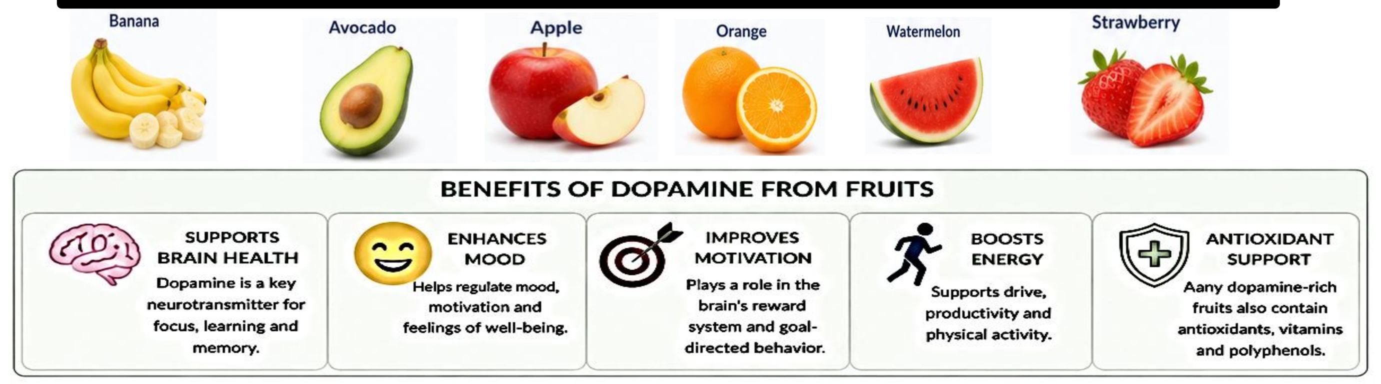
✓ As a **neurotransmitter**, it is a chemical messenger used by the brain and nervous system to transmit signals between neurons

✓ **The need for detection and monitoring is because** hyperactivity and hypoactivity of dopamine lead to various psychiatric, immunological, and neurodegenerative disorders, [1]

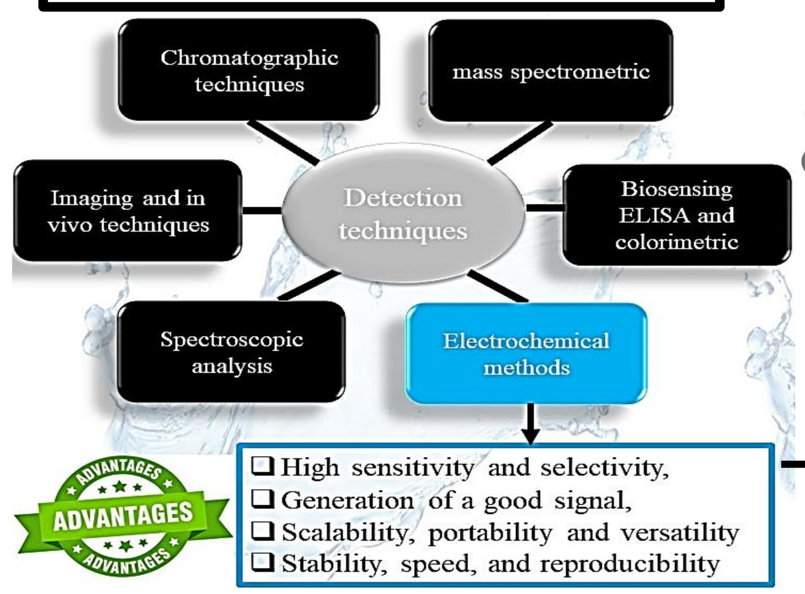
Synthetic pathway for the formation of dopamine in fruits



Fruit sources of dopamine or the amino acid *L-tyrosine*

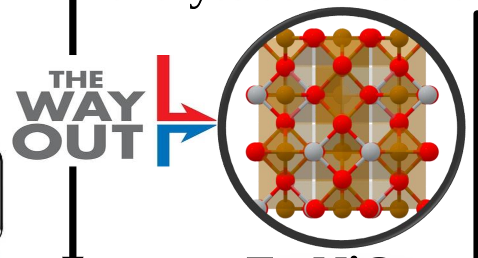


Detection techniques



- ❑ High sensitivity and selectivity,
- ❑ Generation of a good signal,
- ❑ Scalability, portability and versatility
- ❑ Stability, speed, and reproducibility

Electrochemical detection techniques: This method for detecting analytes involves selective binding/chemical interaction of the analyte at the surface of the modified working electrode [4]



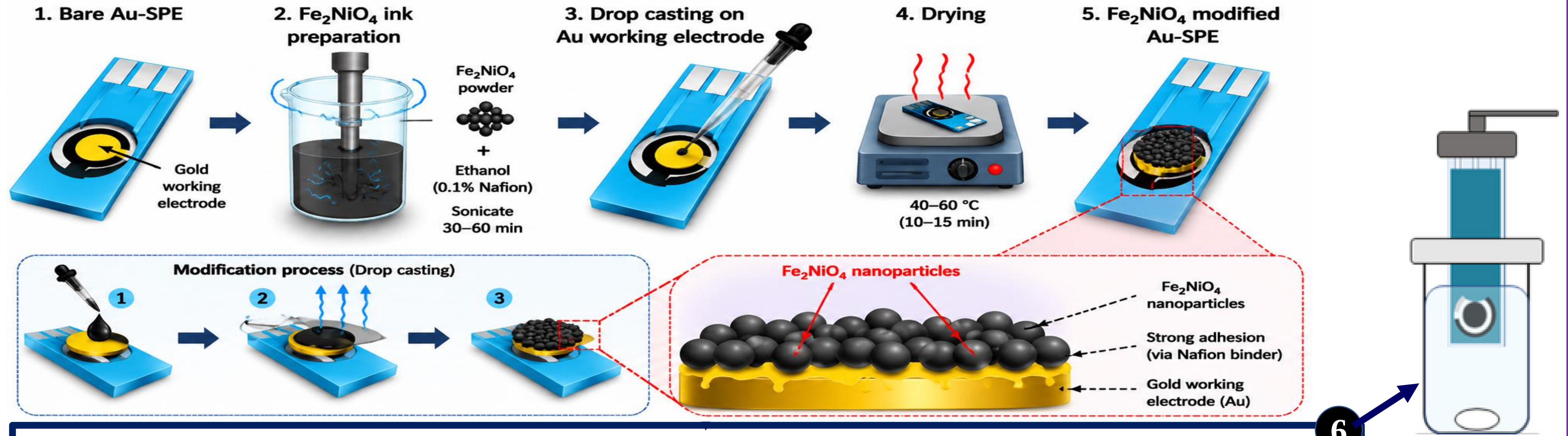
Fe_2NiO_4

- ❑ Excellent chemical stability and cost-effectiveness
- ❑ Large active surface area, superior electrical conductivity and high electrocatalytic activity **[5,6]**

Challenges of the working electrode

- ❑ Sensitivity and selectivity and biocompatibility
- ❑ Electrode fouling, and low stability and a narrow linear range

Materials and Methods



Drying and electrochemical characterization and instrumental analysis

5 mM Potassium ferricyanide/Potassium ferrocyanide In **0.1 M KCl** (supporting electrolyte)

•**Cyclic voltammetry (CV) and linear sweep voltammetry (LSV)**

- Scan rate: **25–200 mV/s** Potential window: typically **−1.0 to 1.0 V (vs Ag/AgCl)**

Results and Discussion

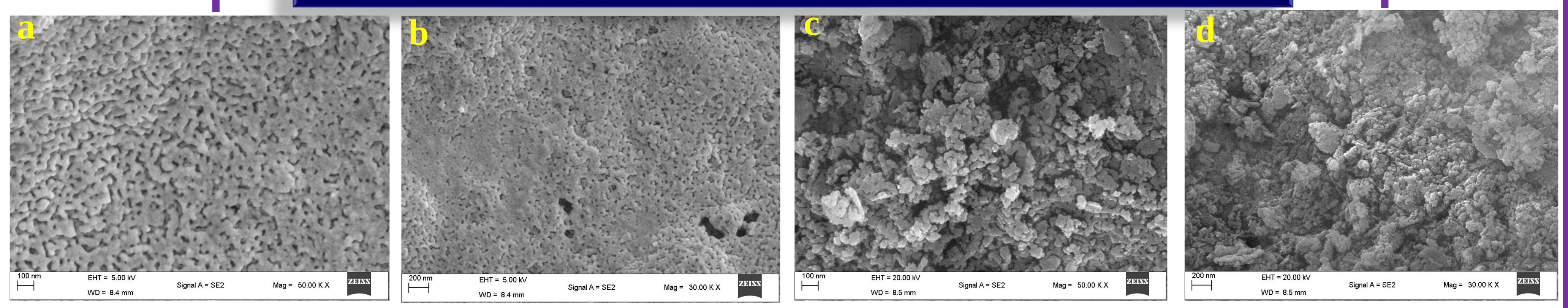


Fig. 1 Scanning electron microscopy image of bare screen-printed gold electrode (a-b) and electrode modifier (c-d)

- ❑From Fig 1(a-b), a **rough, porous, granular morphology** of **interconnected gold nanostructures**.
- ❑From Fig 1 (c-d), the Fe_2NiO_4 (electrode modifier exhibits a highly agglomerated, cauliflower-like nanostructure with rough, porous clusters. This **morphology can provide abundant active sites** and facilitate **efficient electron transfer**. The increased surface area enhances analyte adsorption, improving catalytic activity and sensitivity [4]

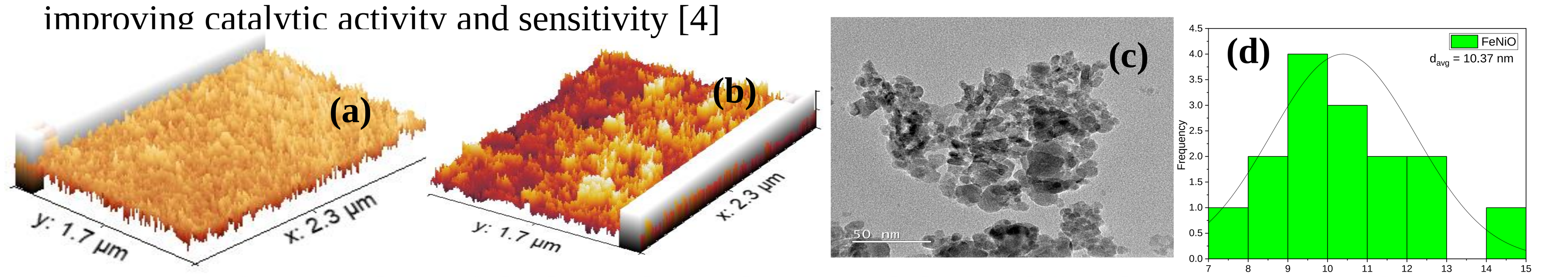


Fig. 2: 3D surface topology of the bare electrode (a); and the modifier (b) TEM image of FeNiO (c); particle size distribution (d)

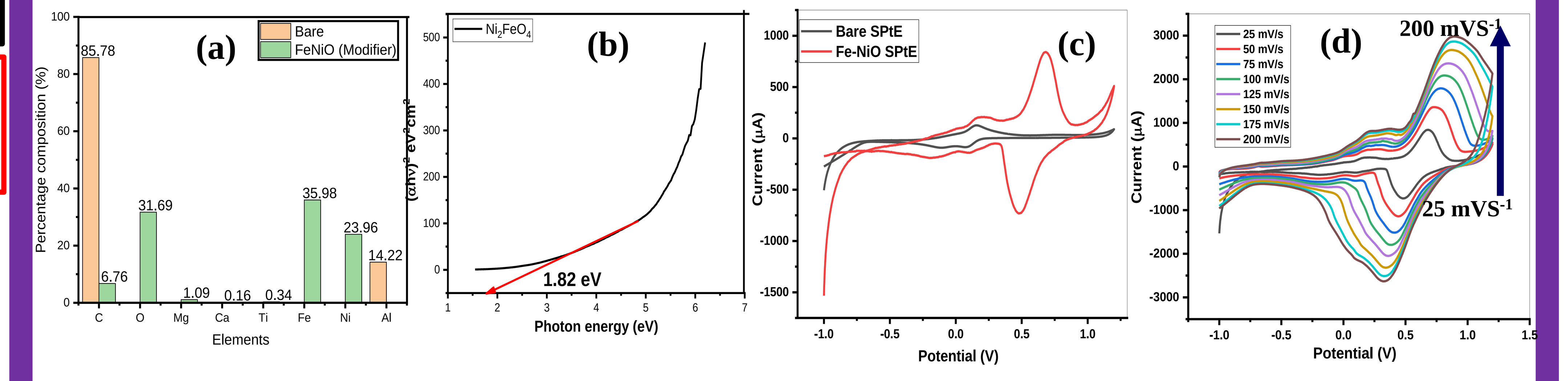


Fig. 3: EDS analysis of Ni_2FeO_4 (a); Tauc plot Ni_2FeO_4 (b); Cyclic voltametric analysis of the bare and modified electrode at 25 mV scan rate (c); the effect of scan rate (d) on the modified electrode

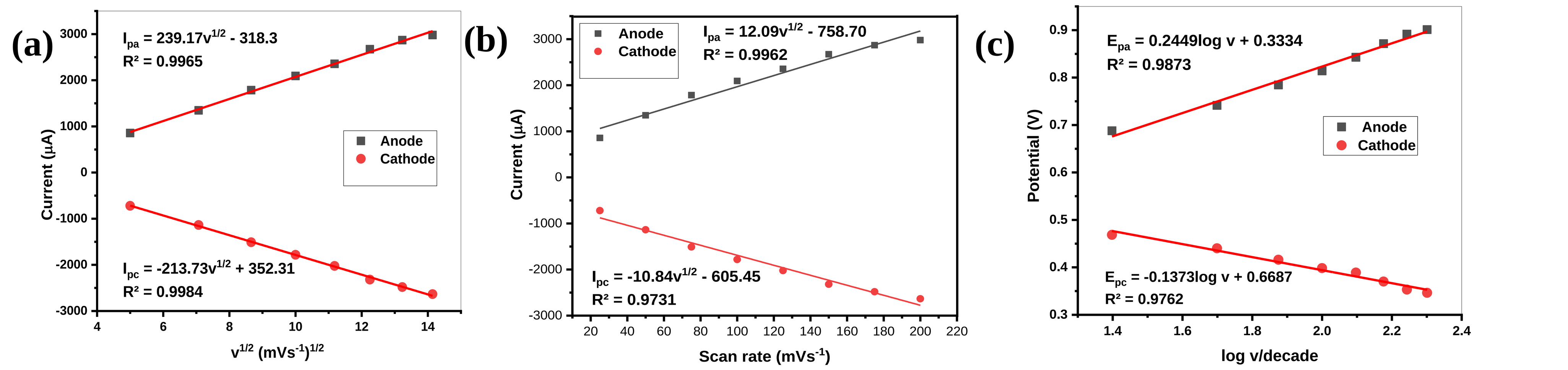


Fig. 4: plot of peak currents vs the square root of scan rates (a) and scan rates (b); peak potentials vs. log of scan rate (v/decade) (c) in 0.1 M PBS pH 7.4 containing 5 mM $K_3[Fe(CN)_6]$

Results and Discussion

- ❑ Using **Randles–Sevcik equation,** the estimated surface area of the bare and modified @ 25 mVs^{-1} are: **Bare electrode area ≈ 0.235 cm²; Modified electrode area ≈ 1.45 cm² (The area available for electrocatalytic activities) I_{pa}/I_{pc} for bare = 1.142 mA; I_{pa}/I_{pc} for modified = 1.43 mA**
- ❑ The I_{pa}/I_{pc} ratio increase indicated enhanced electrocatalytic activity with increased oxidation current. However, the larger deviation from unity suggests the modified electrode exhibits more quasi-reversible behaviour, possible surface adsorption effects, and slightly slower reduction kinetics
- ❑The electrochemical characterization of Fe_2NiO_4 reveals distinct anodic and cathodic behaviour with good linearity, indicating efficient charge-transfer kinetics and stable redox activity. Using the **Laviron equations,** the **number of electron transfer** (n) and **charge transfer coefficient** (α) is approximately 1 and 0.64, indicating efficient and relatively fast electron-transfer kinetics
- ❑For the anodic process = 0.4898 V/dec and the cathodic process 0.2746 V/dec, suggesting adsorption on the surface of the electrode and appreciably fast reaction kinetics during redox processes

Conclusion

- ❑The electrode modifier has a cauliflower-like nanostructure and rough, porous clusters and a particle size of 10.37 nm
- ❑The electrochemical characterization is both simultaneous adsorption and diffusion control
- ❑High surface area 6 times the bare with for electrocatalytic activity and efficient charge-transfer kinetics and stable redox activity

Selected References

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