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Abstract  
The purpose of this study is to investigate the effects of the independent variable on the dependent variable. The study was conducted using a quantitative research design. The data was collected from a sample of participants and analyzed using statistical methods. The results of the study indicate that there is a significant relationship between the independent variable and the dependent variable. The findings suggest that the independent variable has a positive effect on the dependent variable. The study has several limitations, including a small sample size and a lack of control over the independent variable. Future research should aim to address these limitations and further explore the relationship between the independent variable and the dependent variable.  
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## Introduction

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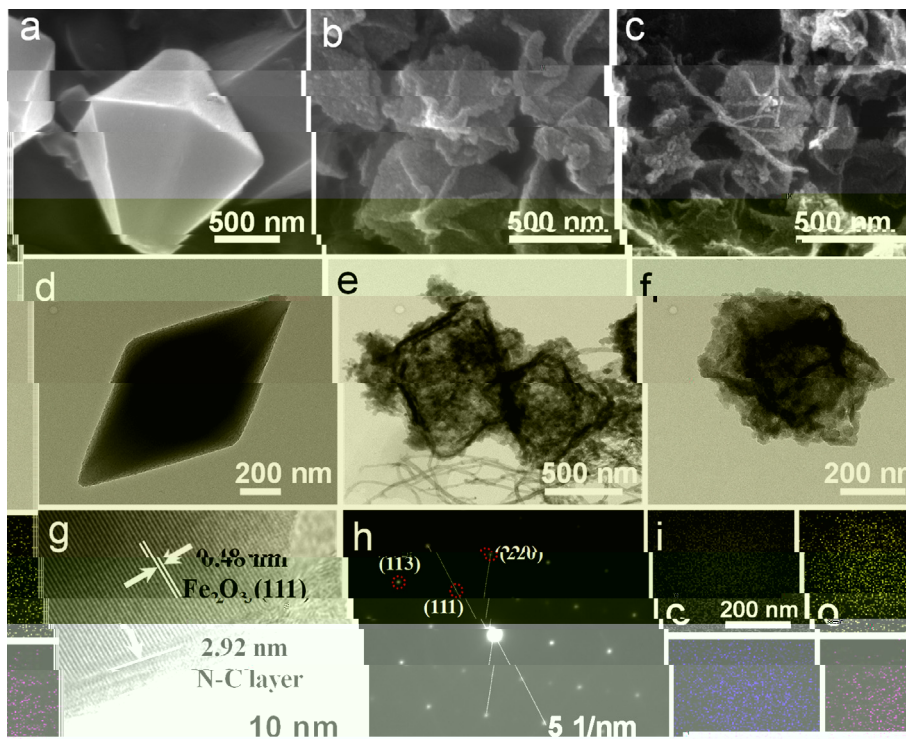
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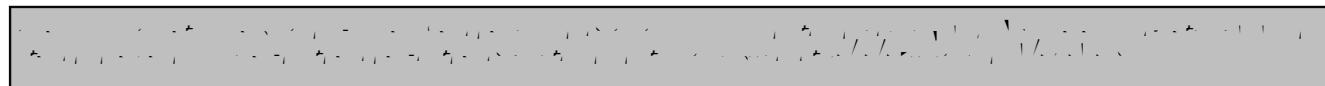
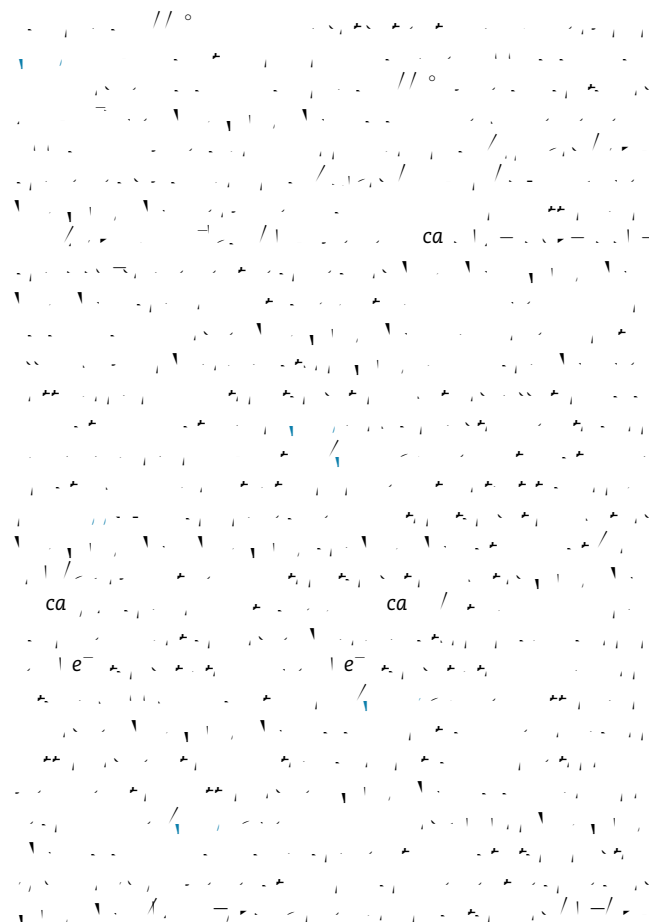
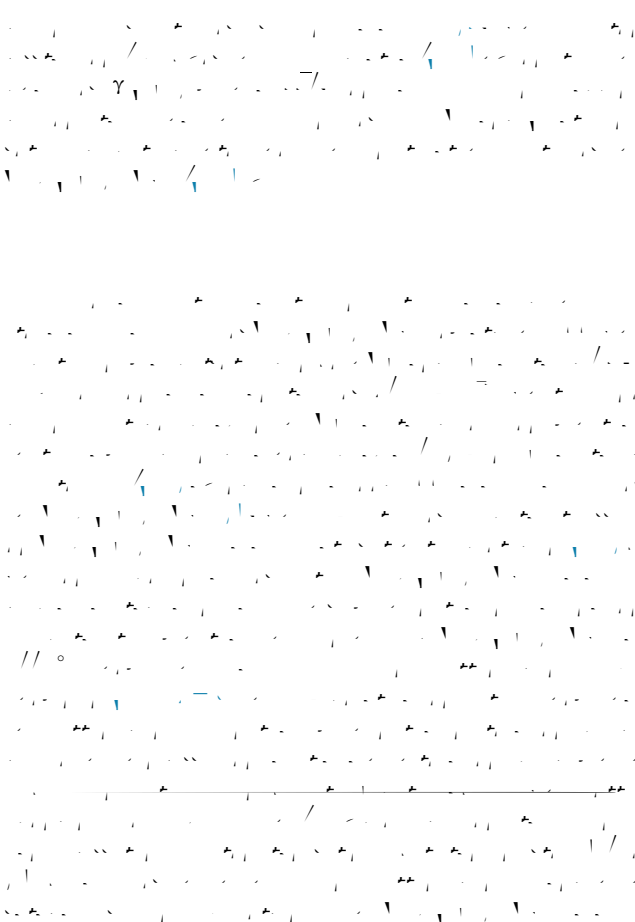
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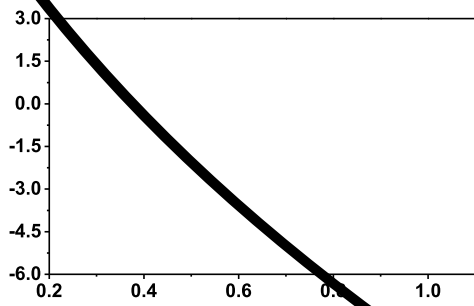
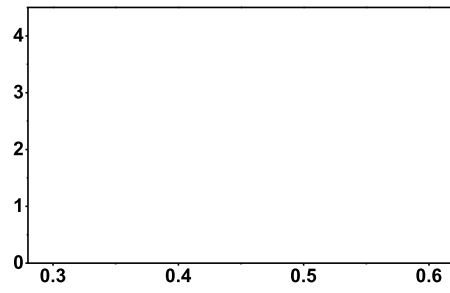
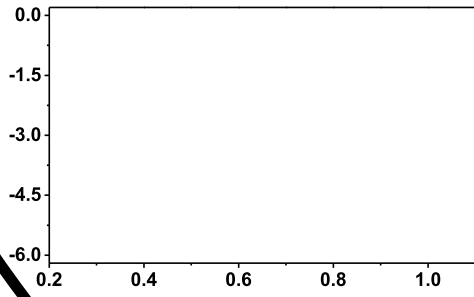
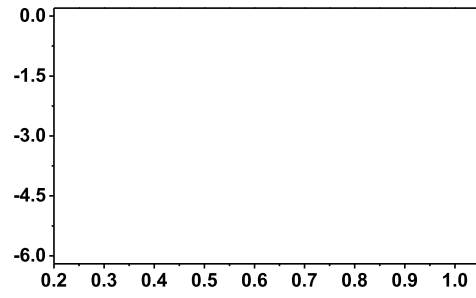
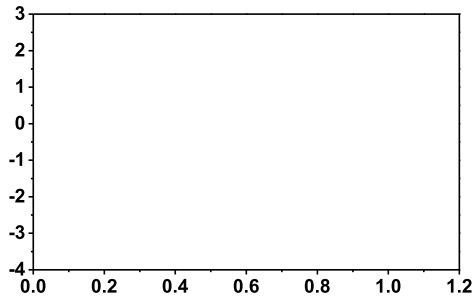


1.  $\int_0^1 x^2 dx = \frac{1}{3}$   
2.  $\int_0^1 x^3 dx = \frac{1}{4}$   
3.  $\int_0^1 x^4 dx = \frac{1}{5}$   
4.  $\int_0^1 x^5 dx = \frac{1}{6}$   
5.  $\int_0^1 x^6 dx = \frac{1}{7}$   
6.  $\int_0^1 x^7 dx = \frac{1}{8}$   
7.  $\int_0^1 x^8 dx = \frac{1}{9}$   
8.  $\int_0^1 x^9 dx = \frac{1}{10}$   
9.  $\int_0^1 x^{10} dx = \frac{1}{11}$   
10.  $\int_0^1 x^{11} dx = \frac{1}{12}$

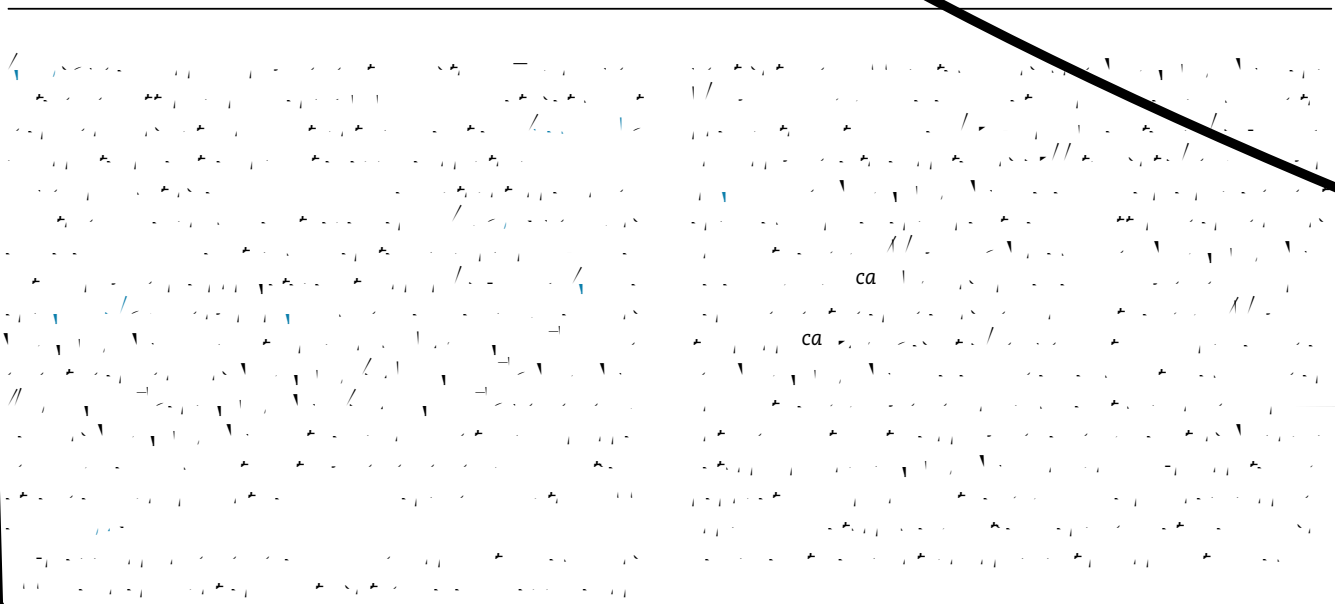


**Fig. 2** – SEM images of (a) MIL-101-Fe crystals, (b) Ppy@MIL-101-Fe-CNTs and (c) NC@Fe<sub>2</sub>O<sub>3</sub>-CNTs. TEM images of (d) MIL-101-Fe crystals, (e) Ppy@MIL-101-Fe-CNTs and (f) NC@Fe<sub>2</sub>O<sub>3</sub>-CNTs. (g) High-resolution TEM image, (h) SAED pattern and (i) HAADF-STEM image and its corresponding elemental mappings of NC@Fe<sub>2</sub>O<sub>3</sub>-CNTs.





0.2



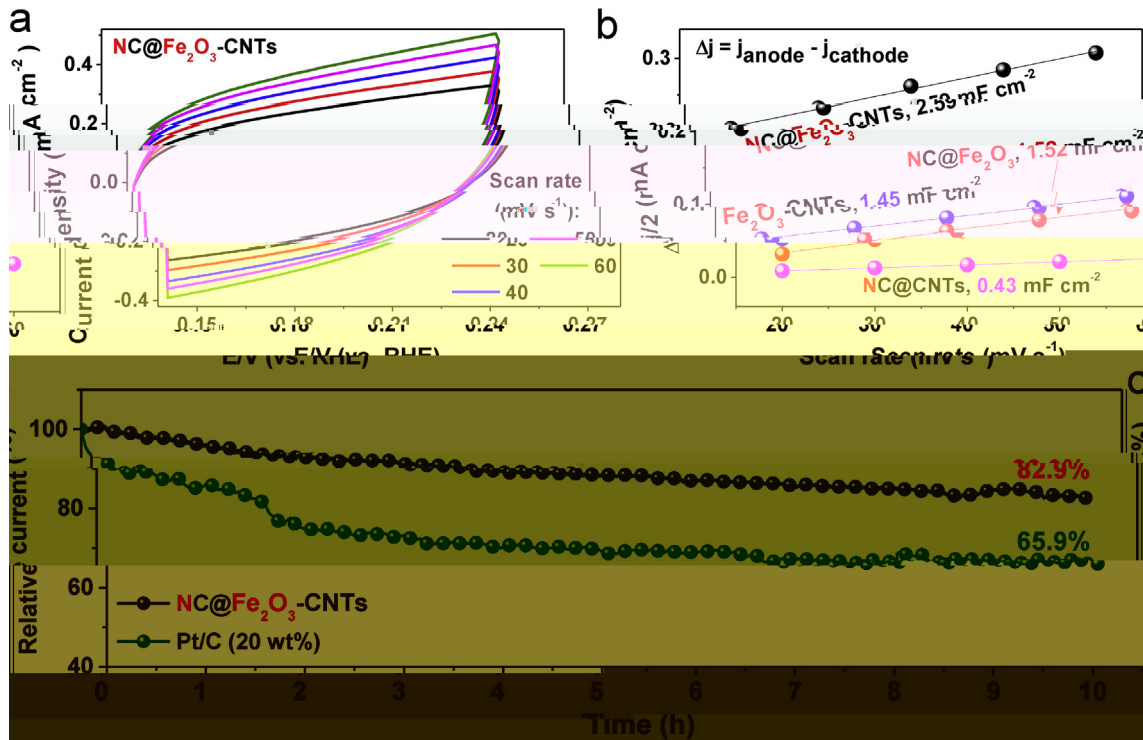


Fig. 4 – (a) Cyclic voltammograms (CV) in a potential window without faradaic processes of NC@Fe<sub>2</sub>O<sub>3</sub>-CNTs and (b) the summarized double-layer capacitance (C<sub>dl</sub>) of different catalysts. (c) Chronoamperometric response of NC@Fe<sub>2</sub>O<sub>3</sub>-CNTs and Pt/C (20 wt %) catalysts at 0.60 V with a rotation speed of 1600 rpm for 10 h in O<sub>2</sub>-saturated 0.1 M KOH.

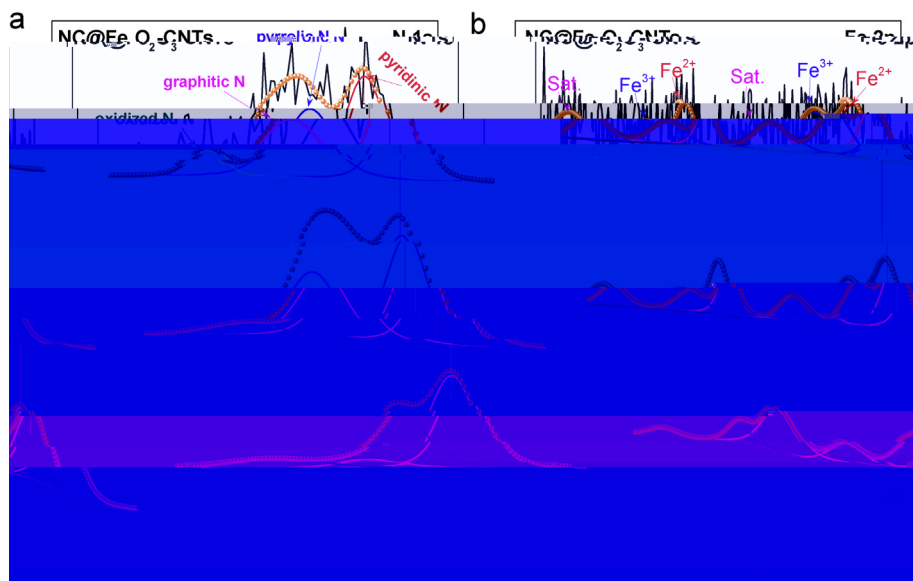
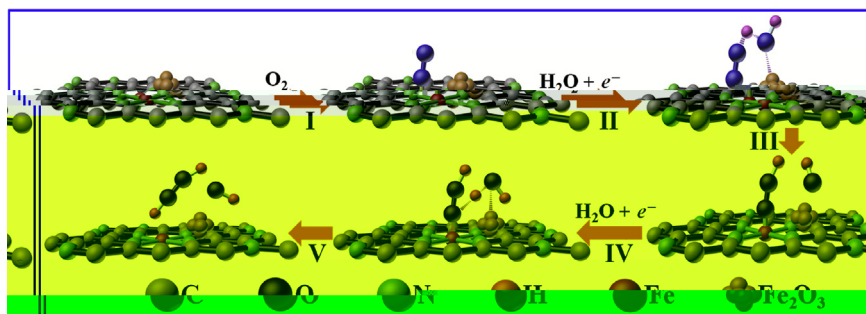


Fig. 5 – High-resolution XPS spectra of (a) N 1s regions of NC@Fe<sub>2</sub>O<sub>3</sub>-CNTs, NC@Fe<sub>2</sub>O<sub>3</sub> and NC@CNTs, and (b) Fe 2p regions of NC@Fe<sub>2</sub>O<sub>3</sub>-CNTs, NC@Fe<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub>-CNTs.



Scheme 2 – The proposed catalytic mechanism of NC@Fe<sub>2</sub>O<sub>3</sub> catalyst for electrochemical O<sub>2</sub> reduction to H<sub>2</sub>O<sub>2</sub> in alkaline medium.

1/2 O<sub>2</sub> + H<sub>2</sub>O + e<sup>-</sup> → OH<sup>-</sup>  
 O<sub>2</sub> + H<sub>2</sub>O + e<sup>-</sup> → HO<sub>2</sub><sup>-</sup>  
 HO<sub>2</sub><sup>-</sup> + H<sub>2</sub>O + e<sup>-</sup> → H<sub>2</sub>O<sub>2</sub> + OH<sup>-</sup>  
 H<sub>2</sub>O<sub>2</sub> + H<sub>2</sub>O + e<sup>-</sup> → H<sub>2</sub>O + OH<sup>-</sup>  
 H<sub>2</sub>O<sub>2</sub> + OH<sup>-</sup> → O<sub>2</sub> + H<sub>2</sub>O + e<sup>-</sup>

## Conclusions

The proposed NC@Fe<sub>2</sub>O<sub>3</sub> catalyst shows excellent catalytic activity for the electrochemical reduction of O<sub>2</sub> to H<sub>2</sub>O<sub>2</sub> in alkaline medium. The catalyst exhibits a high selectivity for H<sub>2</sub>O<sub>2</sub> production and a low overpotential. The proposed mechanism involves the adsorption of O<sub>2</sub> on the CNT surface, followed by its reduction to H<sub>2</sub>O<sub>2</sub> on the CNT surface. The H<sub>2</sub>O<sub>2</sub> is then desorbed from the CNT surface and reduced to H<sub>2</sub>O on the Fe<sub>2</sub>O<sub>3</sub> surface. The Fe<sub>2</sub>O<sub>3</sub> surface also acts as a catalyst for the oxidation of H<sub>2</sub>O<sub>2</sub> to O<sub>2</sub>.

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## Acknowledgements

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at <https://doi.org/10.1016/j.ijhe.2018.12.001>.



## REFERENCES

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1. J. H. Conway and N. J. A. Sloane, *Spherical Designs: An Introduction to the Geometry of Finite Flattened Manifolds*, Cambridge University Press, Cambridge, 1985.
2. J. H. Conway and N. J. A. Sloane, *Sphere Packings, Lattices and Groups*, Springer-Verlag, New York, 1988.
3. J. H. Conway and N. J. A. Sloane, *Sphere Packings, Lattices and Groups*, Springer-Verlag, New York, 1993.
4. J. H. Conway and N. J. A. Sloane, *Sphere Packings, Lattices and Groups*, Springer-Verlag, New York, 1998.
5. J. H. Conway and N. J. A. Sloane, *Sphere Packings, Lattices and Groups*, Springer-Verlag, New York, 2003.
6. J. H. Conway and N. J. A. Sloane, *Sphere Packings, Lattices and Groups*, Springer-Verlag, New York, 2008.
7. J. H. Conway and N. J. A. Sloane, *Sphere Packings, Lattices and Groups*, Springer-Verlag, New York, 2013.
8. J. H. Conway and N. J. A. Sloane, *Sphere Packings, Lattices and Groups*, Springer-Verlag, New York, 2018.
9. J. H. Conway and N. J. A. Sloane, *Sphere Packings, Lattices and Groups*, Springer-Verlag, New York, 2023.
10. J. H. Conway and N. J. A. Sloane, *Sphere Packings, Lattices and Groups*, Springer-Verlag, New York, 2028.

