Electronic Supplementary Material (ESI) for Dalton Transactions.
This journal is © The Royal Society of Chemistry 2024

Electronic Supplementary Information (ESI)

Three-Dimensional Bimodal Pore-rich G/MXene Sponge Amalgamated with Vanadium Diselenide Nanosheets as High-Performance Electrode for Electrochemical Water-Oxidation/Reduction Reaction

Khadija Chaudhary[a], Sonia Zulfiqar[b,c], Zeid A. ALOthman[d], Imran Shakir[d], Muhammad Farooq Warsi[a]* and Eric W. Cochran[c]*

[a]Institute of Chemistry, Baghdad-ul-Jadeed Campus, The Islamia University of Bahawalpur, Bahawalpur, -63100, Pakistan

[b]Department of Chemistry, Faculty of Science, University of Ostrava, 30. Dubna 22, Ostrava 701 03, Czech Republic

[c]Department of Chemical and Biological Engineering, Iowa State University, Sweeney Hall, 618 Bissell Road, Ames, Iowa 50011, United States

[d]Department of Chemistry, College of Science, King Saud University, P. O. Box 2455, Riyadh 11451, Saudi Arabia

Corresponding authors: *farooq.warsi@iub.edu.pk, ecochran@iastate.edu*

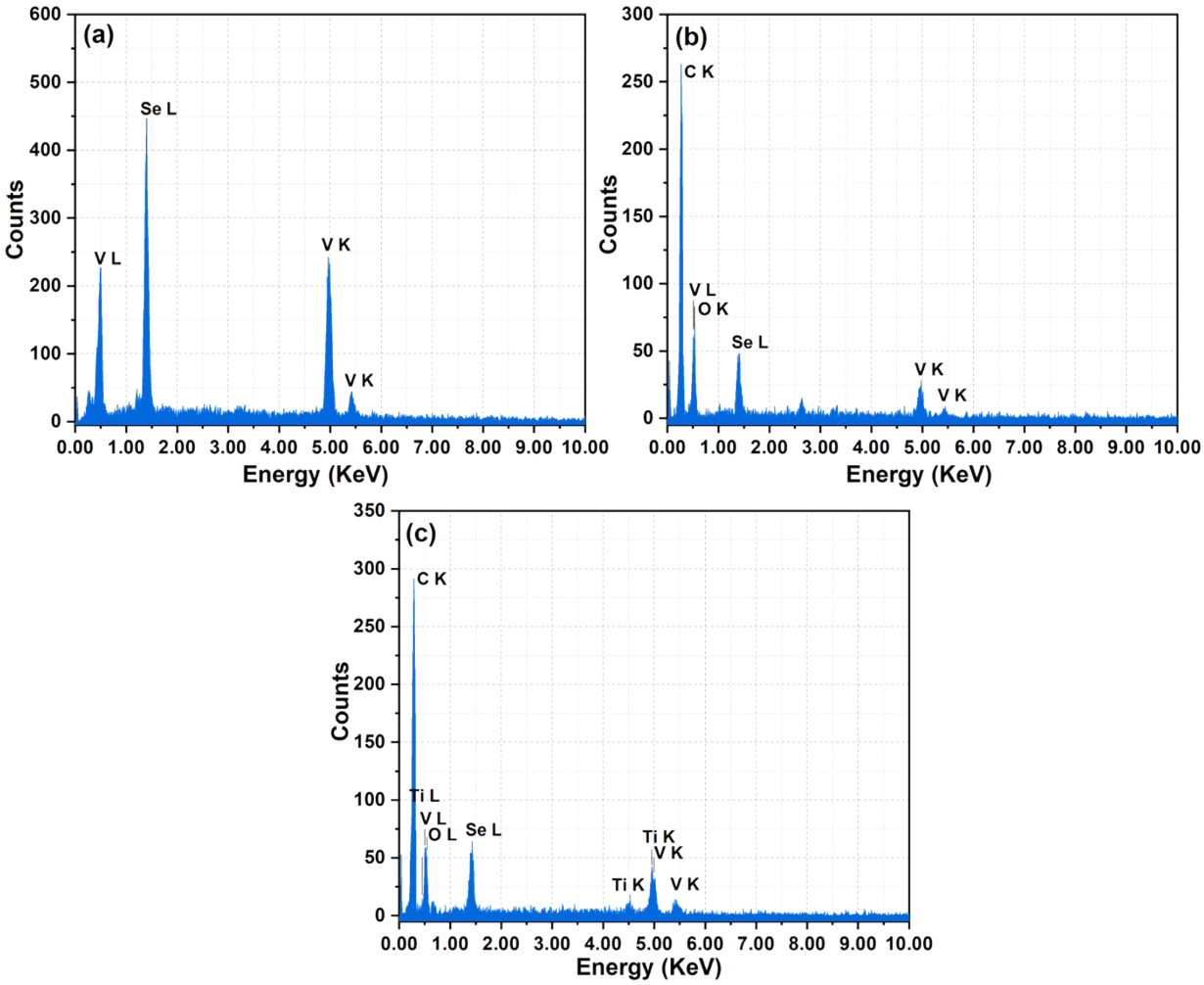

Figure S1. EDX spectra of (a) VSe_2, (b) VSe_2@G, and (c) VSe_2@G/MXe.

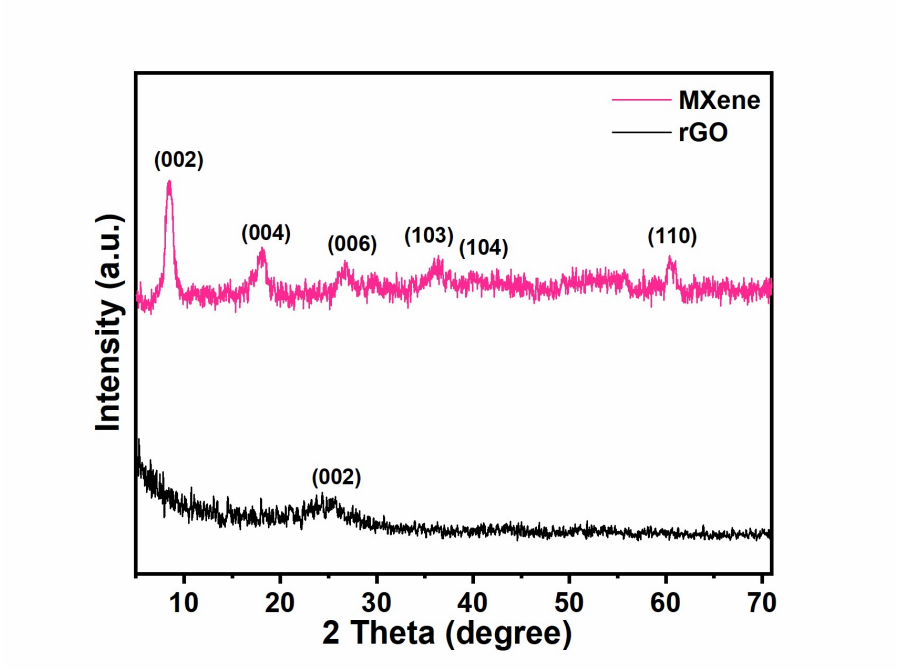

Figure S2. XRD patterns of (a) MXene and (b) rGO.

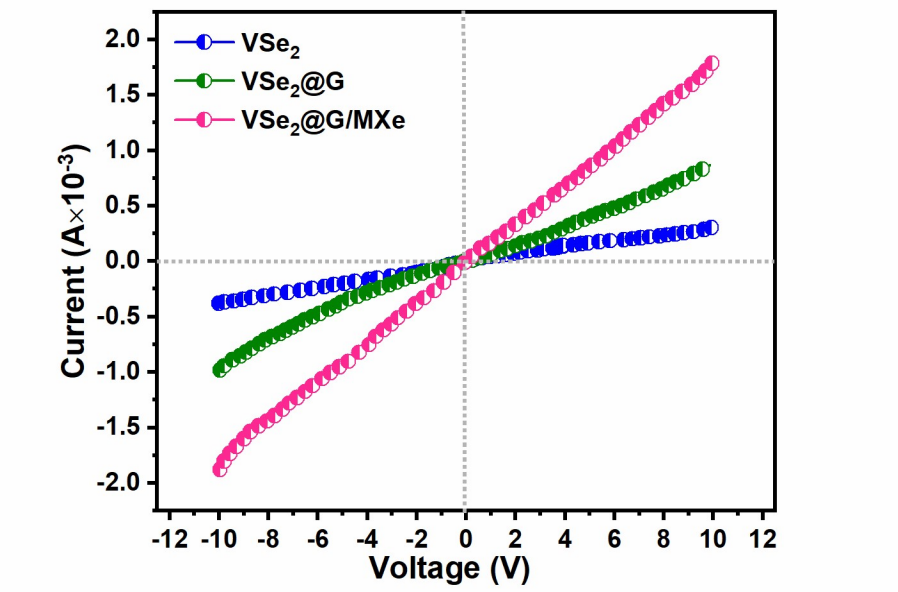

Figure S3. I-V profiles of VSe_2, VSe_2@G, and VSe_2@G/MXe.

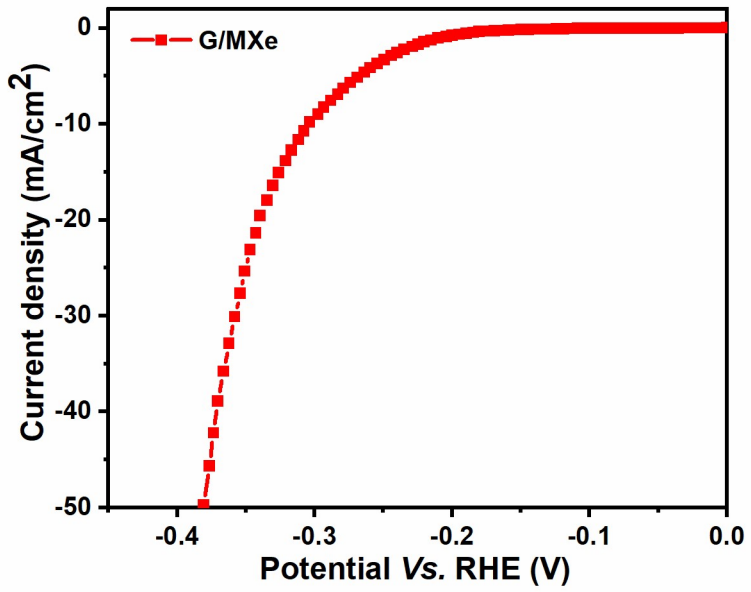

Figure S4. LSV curve of G/MXe for HER.

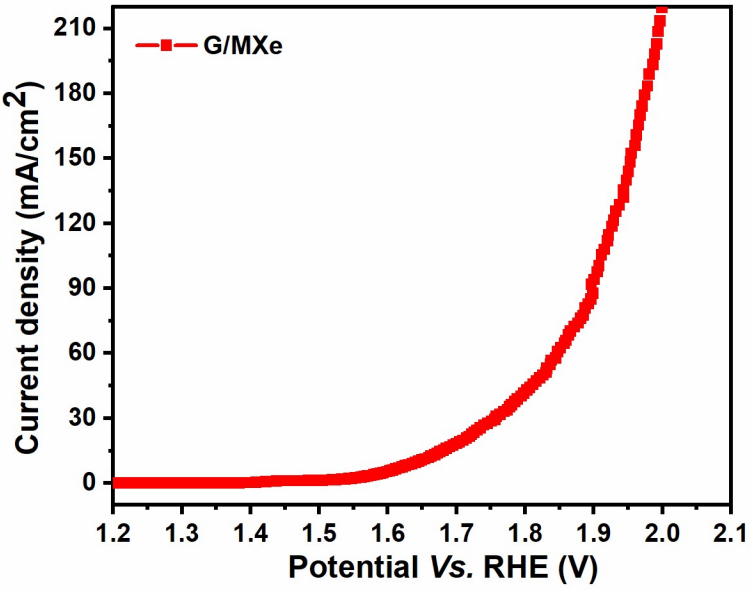

Figure S5. LSV curve of G/MXe for OER.

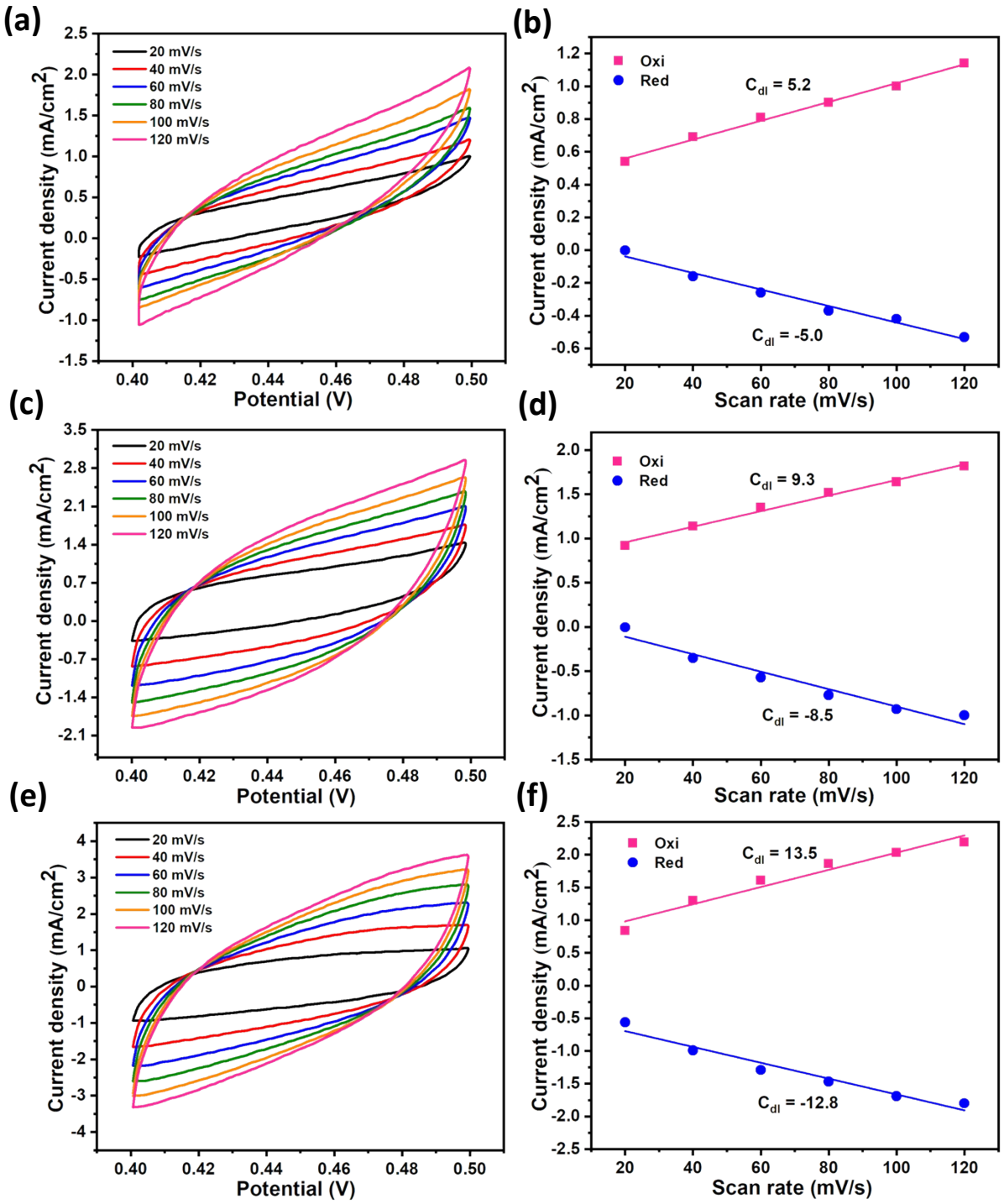

Figure S6. C_{dl} results for VSe_2, VSe_2@G, and VSe_2@G/MXe; (a, c, e) CV plots obtained at different scan rates (20-120 mV/s) and (b, d, f) scan rates vs current density plots for anodic and cathodic scans.

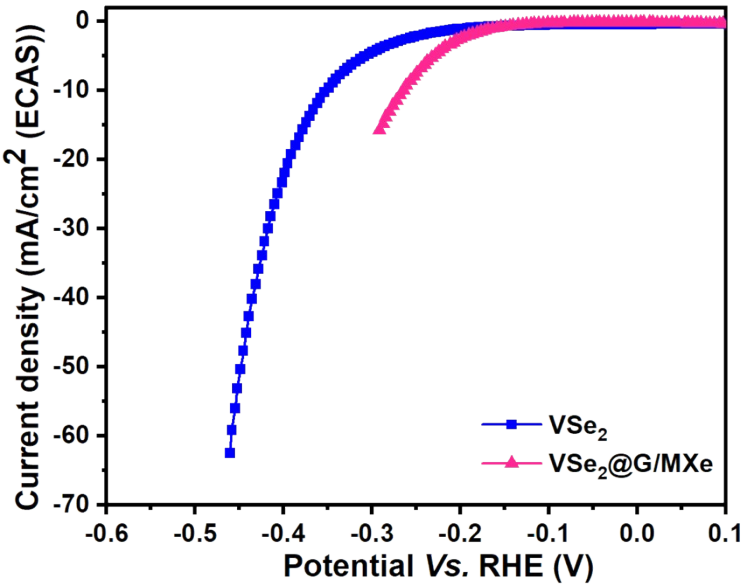

Figure S7. ECAS-normalized LSV curves of VSe_2 and VSe_2@G/MXe for HER.

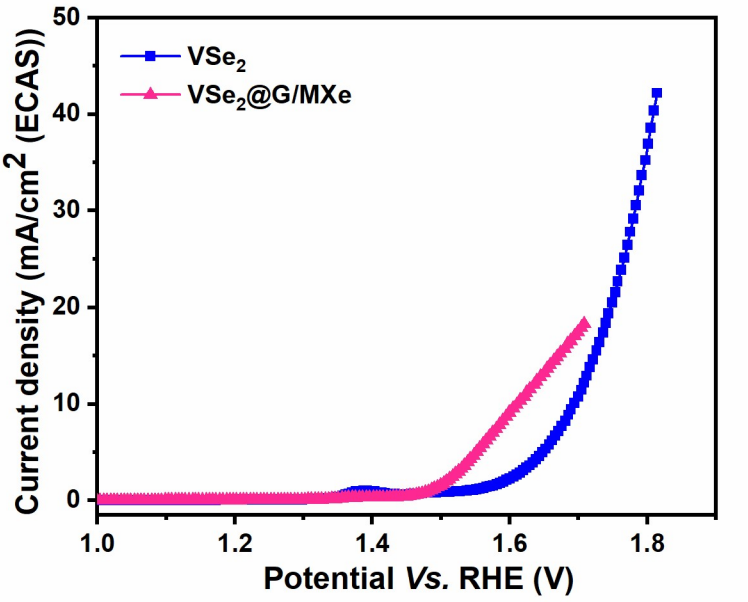

Figure S8. ECAS-normalized LSV curves of VSe_2 and VSe_2@G/MXe for OER.

Table S1. Comparison of HER performance of VSe_2@G/MXe with recently reported electrocatalysts.

Catalyst	Current density (mA/cm^2)	Overpotential/ η (mV)	Tafel slope (mV/dec)	Reference
Co-VSe_2	10	230	63.4	1
VSe_2-MF-NS/CC	10	295	125	2
VSSe Alloy	10	180	87	3
$W_xV_{1-x}Se_2$/CC	10	173	80	4
V_8C_7@Graphene	10	156	89.4	5
VB_2	10	192	68	6
VS_4/rGO	10	210	73	7
VSe_2@G/MXe	10	153	84	Current work

Table S2. Comparison of OER performance of VSe_2@G/MXe with recently reported electrocatalysts.

Catalyst	Current density (mA/cm^2)	Overpotential/ η (mV)	Tafel slope (mV/dec)	Reference
VS_2-rGO (r-V5)	10	300.58	229.9	8
VTe-CNT	10	278	-	9
$Co_{0.67}V_{0.33}P$@CC	10	290	55.59	10
C@Ag-V_2O_5	10	388	71	11
CoV_2O_6–V_2O_5/NRGO	10	239	49.7	12
VSe_2@rGO	10	280	77	13
$Co_{0.75}V_{0.25}$-HNNs	10	268	80	14
VSe_2@G/MXe	10	241	87	Current work

References

(1) Zhu, Q.; Shao, M.; Yu, S. H.; Wang, X.; Tang, Z.; Chen, B.; Cheng, H.; Lu, Z.; Chua, D.; Pan, H. One-pot synthesis of Co-doped VSe_2 nanosheets for enhanced hydrogen evolution reaction. *ACS Applied Energy Materials* **2018**, *2* (1), 644-653.

(2) Miao, C.; Zhang, T.; Li, F.; Zhang, L.; Sun, J.; Liu, D.; Wu, L.; Wang, H.; Chen, F.; He, L. Defect-engineered three-dimensional vanadium diselenide microflowers/nanosheets on carbon cloth by chemical vapor deposition for high-performance hydrogen evolution reaction. *Nanotechnology* **2021**, *32* (26), 265402.

(3) Hu, P.; Long, G.; Chaturvedi, A.; Wang, S.; Tan, K.; He, Y.; Zheng, L.; Liu, G.; Ke, Y.; Zhou, Y. Agent-assisted VSSe ternary alloy single crystals as an efficient stable electrocatalyst for the hydrogen evolution reaction. *Journal of Materials Chemistry A* **2019**, *7* (26), 15714-15721.

(4) Kumar, G. M.; Cho, H.; Ilanchezhiyan, P.; Lee, D.; Jeon, H.; Walke, P. D.; Kim, D.; Kang, T. 3D flexible $W_xV_{1-x}Se_2$ nanoplates arrays on carbon cloth as an novel efficient hydrogen evolution electrocatalysts. *Applied Surface Science* **2021**, *540*, 148297.

(5) Fu, W.; Wang, Y.; Zhang, H.; He, M.; Fang, L.; Yang, X.; Huang, Z.; Li, J.; Gu, X.; Wang, Y. Epitaxial growth of graphene on V_8C_7 nanomeshs for highly efficient and stable hydrogen evolution reaction. *Journal of catalysis* **2019**, *369*, 47-53.

(6) Jothi, P. R.; Zhang, Y.; Yubuta, K.; Culver, D.; Conley, M.; Fokwa, B. Abundant vanadium diboride with graphene-like boron layers for hydrogen evolution. *ACS Applied Energy Materials* **2018**, *2* (1), 176-181.

(7) Das, J. K.; Samantara, A. K.; Nayak, A. K.; Pradhan, D.; Behera, J. VS_2: an efficient catalyst for an electrochemical hydrogen evolution reaction in an acidic medium. *Dalton Transactions* **2018**, *47* (39), 13792-13799.

(8) Bhosale, M.; Thangarasu, S.; Murugan, N.; Kim, Y. A.; Oh, T.-H. Engineering 2D heterostructured VS_2-rGO-Ni nanointerface to stimulate electrocatalytic water splitting and supercapacitor applications. *Journal of Energy Storage* **2023**, *73*, 109133.

(9) Bano, N.; Manzoor, S.; Sami, A.; Shah, S. I. A.; Junaid, A.; Rehman, M. Y. U.; Alshgari, R. A.; Ehsan, M. F.; Ashiq, M. N. Fabrication of vanadium telluride anchored on carbon nanotubes nanocomposite for overall water splitting. *Journal of the American Ceramic Society* **2024**.

(10) Han, H.; Yi, F.; Choi, S.; Kim, J.; Kwon, J.; Park, K.; Song, T. Self-supported vanadium-incorporated cobalt phosphide as a highly efficient bifunctional electrocatalyst for water splitting. *Journal of Alloys and Compounds* **2020**, *846*, 156350.

(11) Irshad, A.; Zulfiqar, S.; Alothman, Z. A.; Shakir, I.; Warsi, M. F.; Cochran, E. W. Synergy of zero-dimensional carbon dots decoration on the one-dimensional architecture of Ag-doped V_2O_5 for supercapacitor and overall water-splitting applications. *Fuel* **2024**, *362*, 130705.

(12) Shen, F.-C.; Wang, Y.; Tang, Y.-J.; Li, S.-L.; Wang, Y.-R.; Dong, L.-Z.; Li, Y.-F.; Xu, Y.; Lan, Y.-Q. CoV_2O_6–V_2O_5 coupled with porous N-doped reduced graphene oxide composite as a highly efficient electrocatalyst for oxygen evolution. *ACS Energy Letters* **2017**, *2* (6), 1327-1333.

(13) Samal, R.; Shinde, P. V.; Rout, C. S. 2D Vanadium diselenide supported on reduced graphene oxide for water electrolysis: a comprehensive study in alkaline media. *Emergent Materials* **2021**, *4* (4), 1047-1053.
(14) Yang, M.; Fu, X.; Shao, M.; Wang, Z.; Cao, L.; Gu, S.; Li, M.; Cheng, H.; Li, Y.; Pan, H. Cobalt-Vanadium Hydroxide Nanoneedles with a Free-Standing Structure as High-Performance Oxygen Evolution Reaction Electrocatalysts. *ChemElectroChem* **2019**, *6* (7), 2050-2055.