Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supporting Information

One-step Synthesis of $CeFeO_3$ Nanoparticles on Porous-rich Nanocarbon Frameworks Derived from ZIF-8 for Boosted Oxygen Reduction Reaction in pH Value Universal Electrolytes

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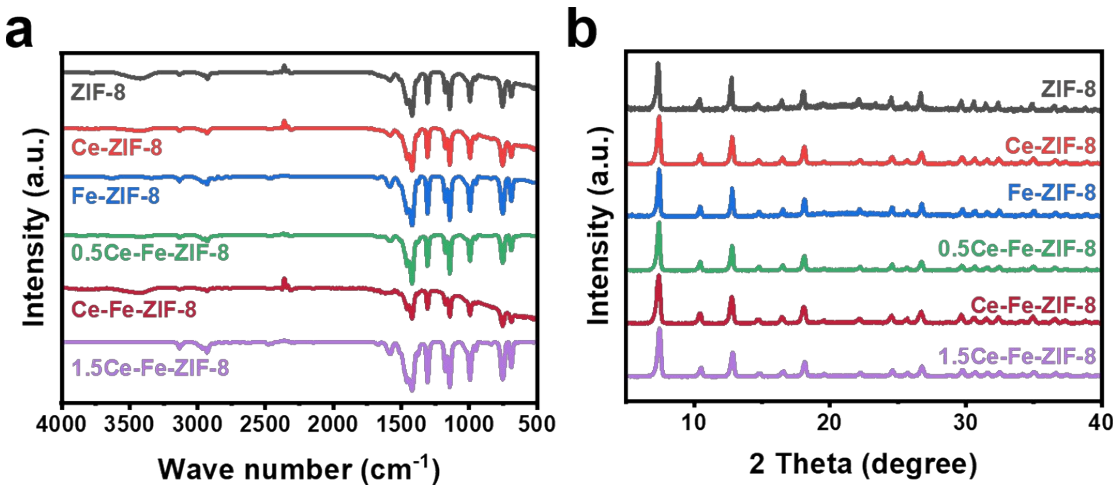

Fig. S1. a) FTIR spectra. b) XRD patterns of ZIF-8, Ce-ZIF-8, Fe-ZIF-8, 0.5Ce-Fe-ZIF-8, Ce-Fe-ZIF-8, 1.5Ce-Fe-ZIF-8.

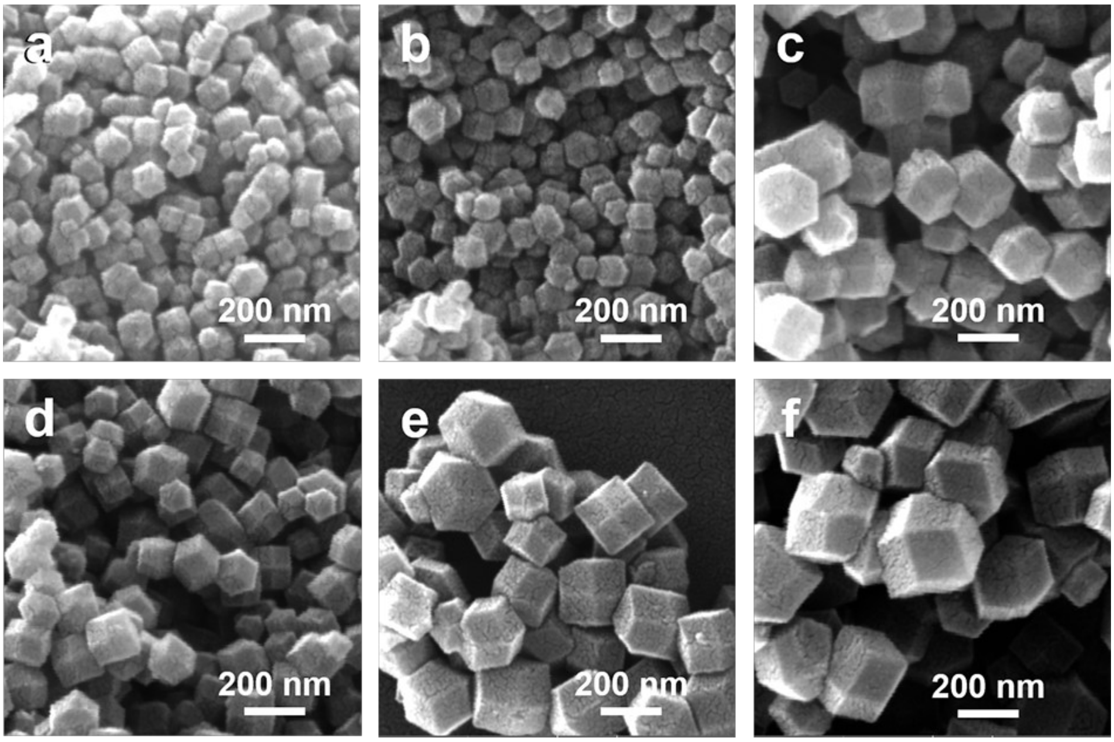

Fig. S2. SEM images of a) NC, b) Ce/NC, c) Fe/ NC, d) 0.5Ce-Fe/NC, e) Ce-Fe/NC, f) 1.5Ce-Fe/NC.

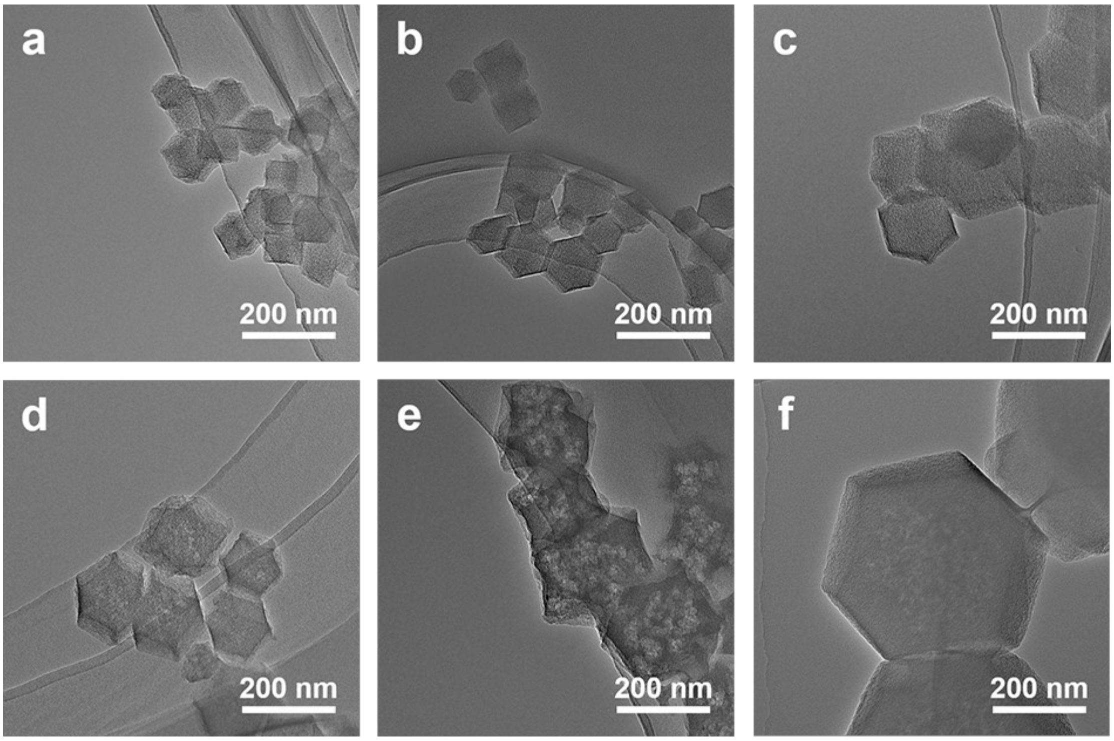

Fig. S3. TEM images of a) NC, b) Ce/NC, c) Fe/NC, d) 0.5Ce-Fe/NC, e) Ce-Fe/NC, f) 1.5Ce-Fe/NC.

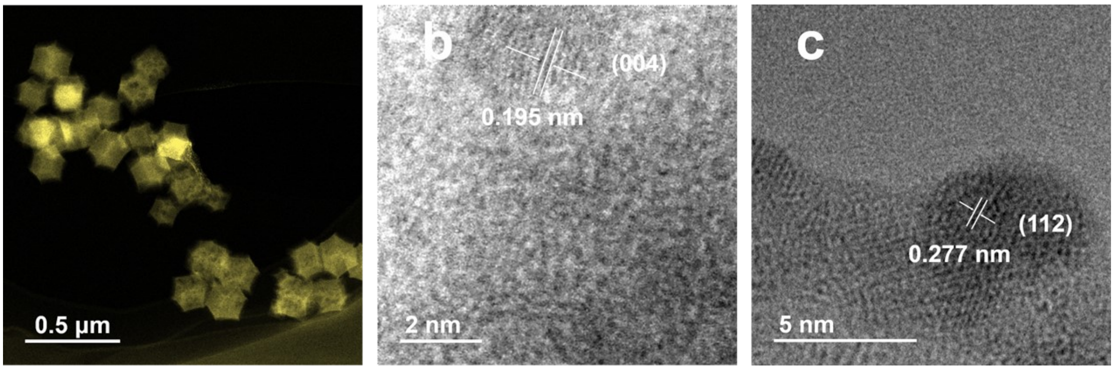

Fig. S4. a) HAADF-STEM image of Ce-Fe/NC. b) HRTEM image of Ce-Fe/NC. c) HRTEM images of Ce-Fe/NC.

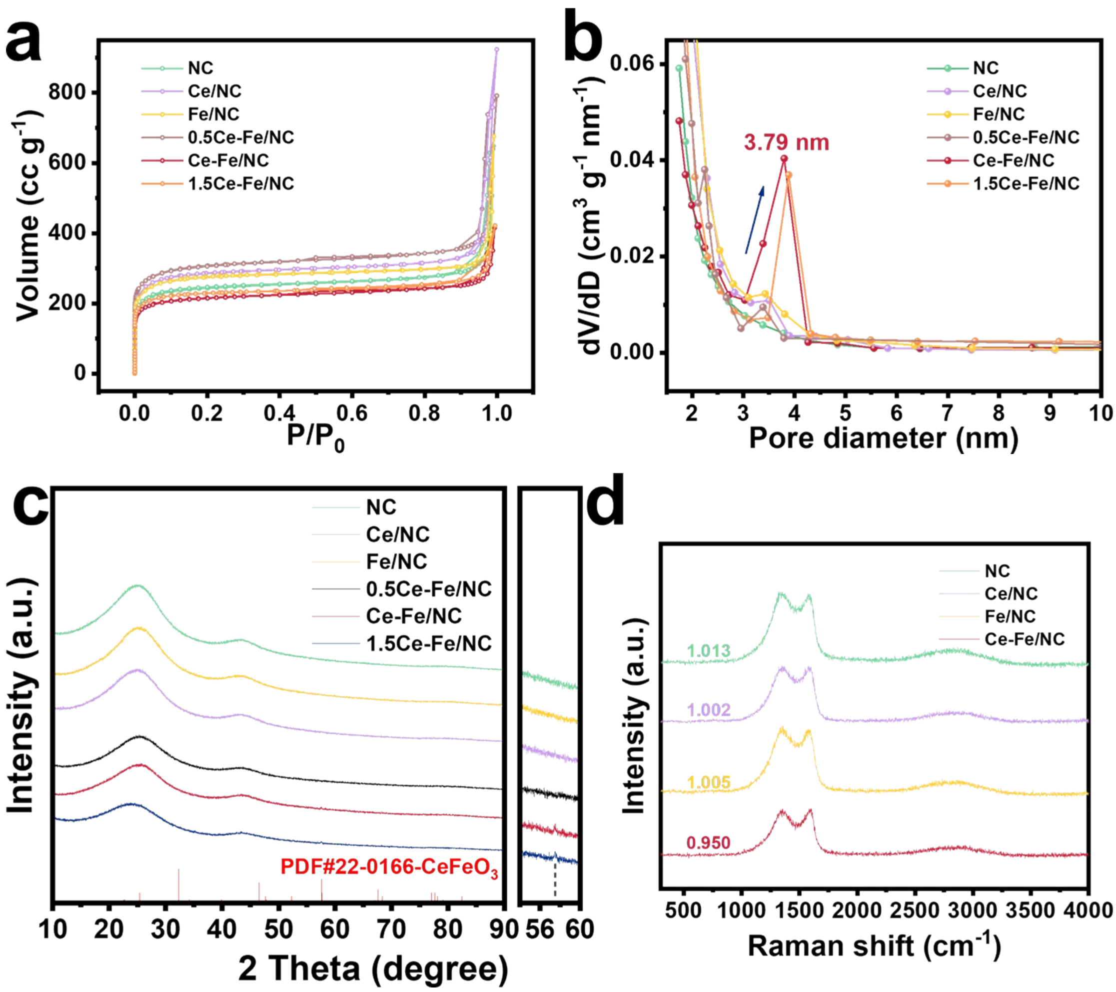

Fig. S5. a) N_2 adsorption/desorption isotherms of NC, Ce/NC, Fe/NC, 0.5Ce-Fe/NC, Ce-Fe/NC, 1.5Ce-Fe/NC. b) The pore diameter distribution of NC, Ce/NC, Fe/NC, 0.5Ce-Fe/NC, Ce-Fe/NC, 1.5Ce-Fe/NC. c) The XRD patterns of NC, Ce/NC, Fe/NC, 0.5Ce-Fe/NC, Ce-Fe/NC and 1.5Ce-Fe/NC. d) The Raman spectra of NC, Ce/NC, Fe/NC, Ce-Fe/NC.

There is a distribution of mesopores at 2.24 nm and 3.38 nm in the 0.5Ce-Fe/NC sample. Increasing the addition amount of Fe and Ce, there is a slight increase in the diameter of mesopores in Ce-Fe/NC (3.79 nm) and 1.5Ce-Fe/NC (3.88 nm).

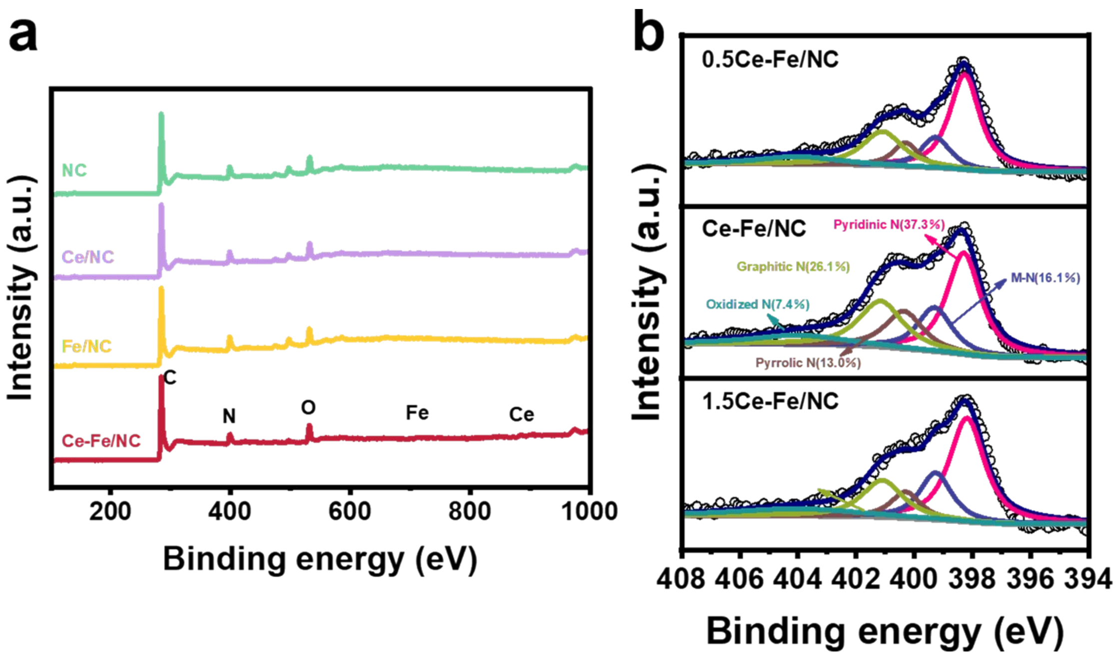

Fig. S6. a) The XPS spectra showing the chemical composition in NC, Ce/NC, Fe/NC, and Ce-Fe/NC. b) XPS N 1s spectra for 0.5Ce-Fe/NC, Ce-Fe/NC and 1.5Ce-Fe /NC.

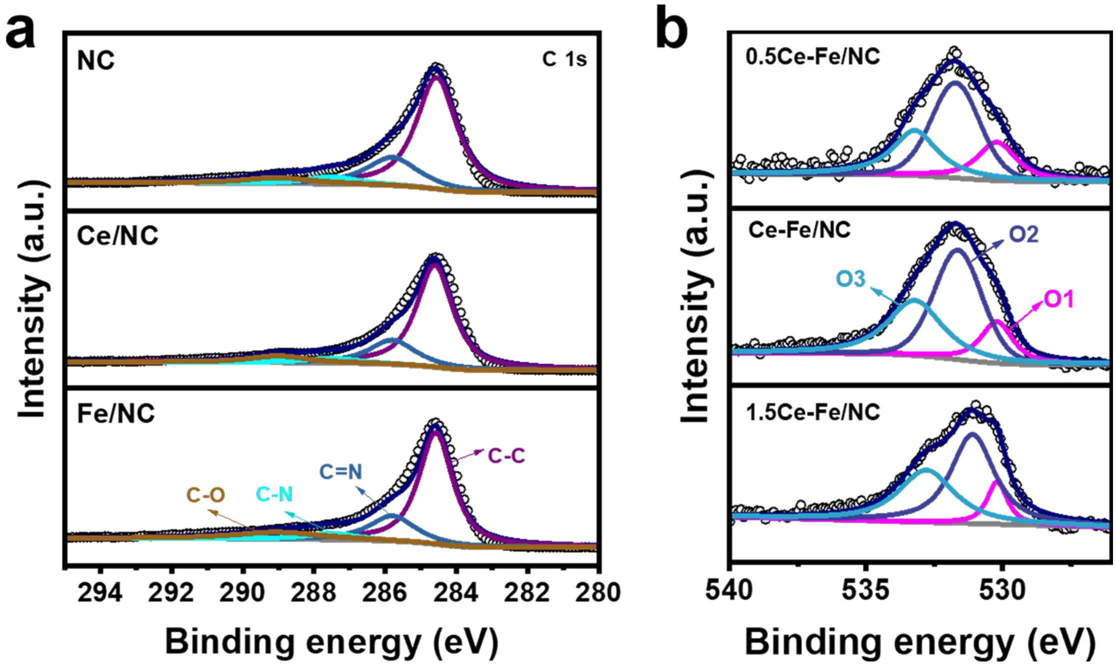

Fig. S7. a) The XPS C 1s regions of NC, Ce/NC, Fe/NC. b) O 1s spectra for 0.5Ce-Fe/NC, Ce-Fe/NC and 1.5Ce-Fe /NC.

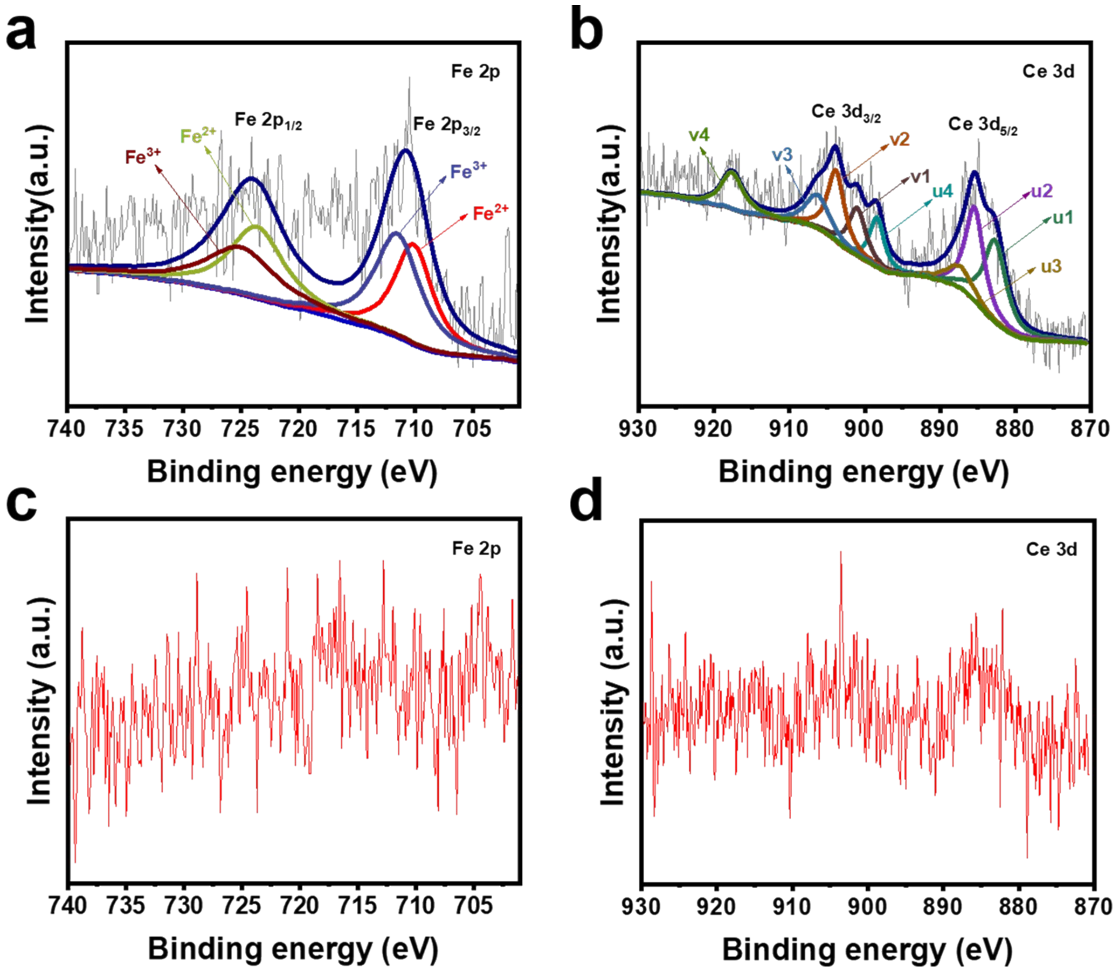

Fig. S8. The XPS Fe 2p regions of a) Ce-Fe/NC and c) Fe/NC. The XPS Ce 3d regions for b) Ce-Fe/NC and d) Ce/NC.

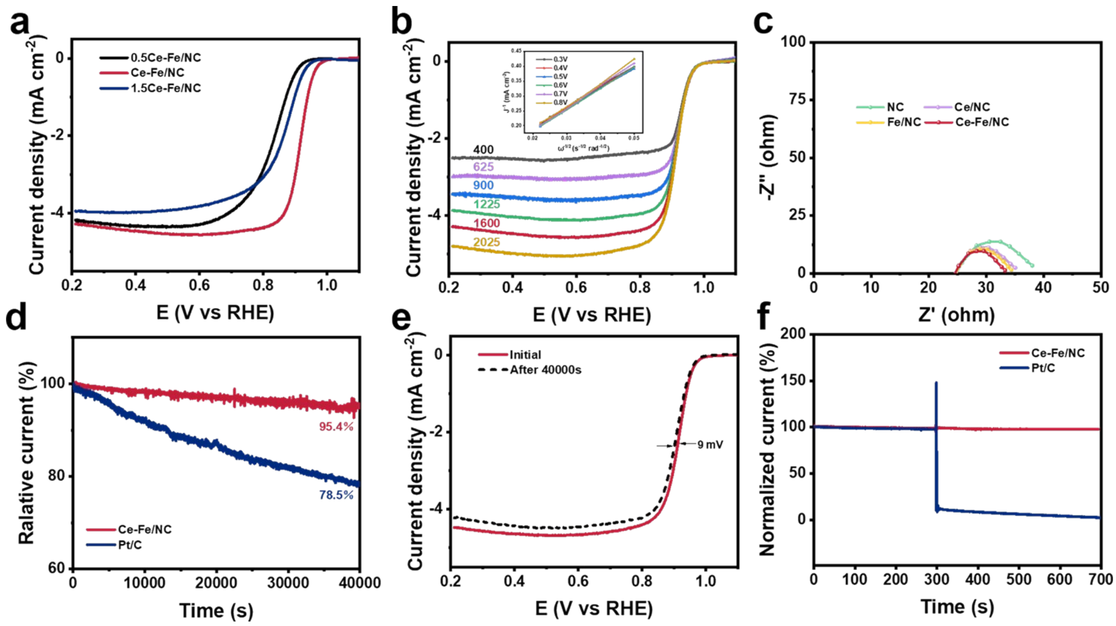

Fig. S9. a) ORR curves of 0.5Ce-Fe/NC, Ce-Fe/NC, 1.5Ce-Fe/NC in 0.1 M KOH electrolyte. b) The polarization curves of Ce-Fe/NC at different rotating speeds; the inset is the corresponding K-L plots. c) Nyquist plots of NC, Ce /NC, Fe/NC and Ce-Fe/NC. d) Chronoamperometric curves of Ce-Fe/NC and Pt/C at 0.7 V versus RHE. e) ORR polarization curves of Ce-Fe/NC before and after 40000 s test at 0.7 V. f) Methanol toxicity tolerance tests of the Ce-Fe/NC and Pt/C by injecting 3% volume of methanol into the electrolyte.

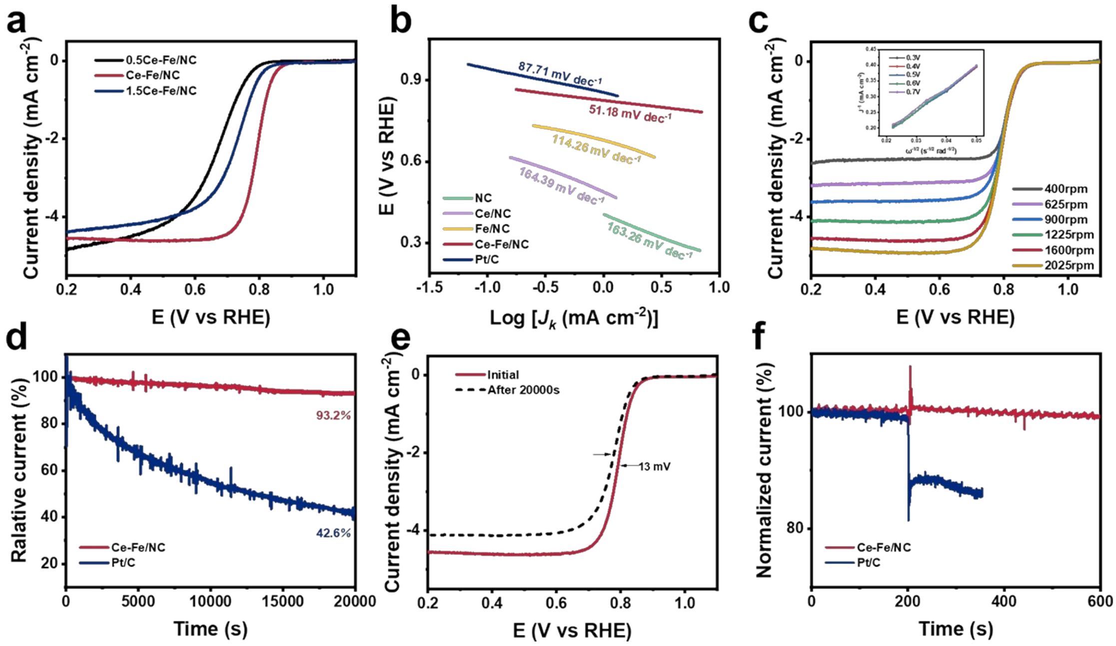

Fig. S10. a) ORR curves of 0.5Ce-Fe/NC, Ce-Fe/NC, 1.5Ce-Fe/NC in 0.1 M $HClO_4$ electrolyte. b) Tafel slopes of NC, Ce/NC, Fe/NC, Ce-Fe/NC and Pt/C. c) The polarization curves of Ce-Fe/NC at different rotating speeds; the inset is the corresponding K-L plots. d) Chronoamperometric curves of Ce-Fe/NC and Pt/C at 0.5 V versus RHE. e) ORR polarization curves of Ce-Fe/NC before and after 20000 s test at 0.5 V. f) Methanol toxicity tolerance tests of the Ce-Fe/NC and Pt/C by injecting 3% volume of methanol into the electrolyte.

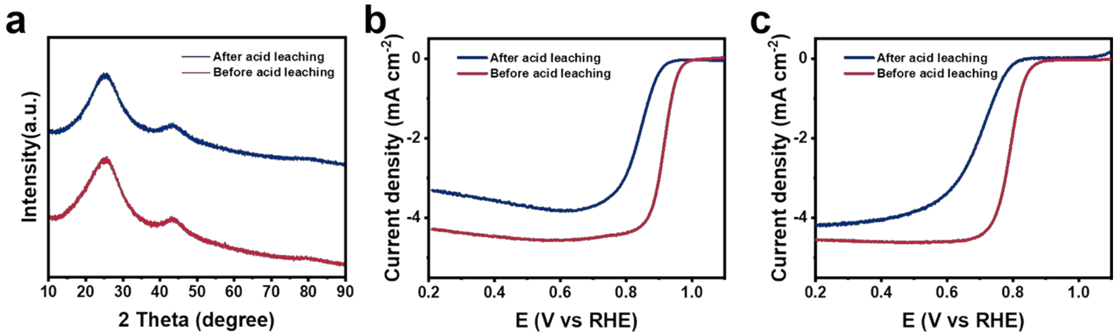

Fig. S11. a) XRD patterns of Ce-Fe/NC before and after 1 M H_2SO_4 acid leaching. ORR polarization curves of Ce-Fe/NC before and after 1 M H_2SO_4 acid leaching in b) 0.1M KOH electrolyte and c) 0.1M $HClO_4$ electrolyte.

Table S1. The doping content of Ce and Fe in the samples characterized by ICP-OES.

Catalyst materials	Ce (wt %)	Fe (wt %)
Ce/NC	0.8	
Fe/NC		0.84
Ce-Fe/NC	0.83	0.88

Table S2. The BET surface area of as-prepared catalysts.

Catalyst materials	BET surface area (m^2 g^{-1})
NC	939
Ce/NC	1088
Fe/NC	1045
0.5Ce-Fe/NC	1170
Ce-Fe/NC	831
1.5Ce-Fe/NC	883

Table S3. Chemical compositions of as-prepared catalysts detected by XPS spectra.

Catalyst materials	C (at. %)	O (at. %)	N (at. %)	Ce (at. %)	Fe (at. %)
NC	82.92	7.76	9.31	0	0
Ce/NC	81.87	8.43	9.51	0.18	0
Fe/NC	81.22	7.73	10.57	0	0.47
0.5Ce-Fe/NC	83.61	5.1	10.58	0.19	0.48
Ce-Fe/NC	83.36	7.74	8.05	0.29	0.54
1.5Ce-Fe/NC	80.4	8.99	9.63	0.31	0.66

Table S4. The NC, Ce/NC, Fe/NC and Ce-Fe/NC samples contents of various N-type.

Catalyst materials	Pyridinic N (%)	M-N (%)	Pyrrolic N (%)	Graphitic N (%)	Oxidized N (%)
NC	50.7	0	28.2	14.3	6.6
Ce/NC	56	6.6	12.6	20.1	4.6
Fe/NC	54.9	7.5	11.7	22.4	3.3
0.5Ce-Fe/NC	45.6	13.9	9.5	21.6	9.4
Ce-Fe/NC	37.3	16.1	13	26.1	7.4
1.5Ce-Fe/NC	43.9	17.9	9.4	18.1	10.7

Table S5. ORR performance comparison for typical non-precious-metal catalysts.

Catalysts materials	$E_{1/2}$		Ref.
	In alkaline media	In acidic media	
p-Fe-NCNFs	0.82	0.74	1
C-FeHZ8@g-C_3N_4-950	0.845	0.78	2
Zn/CoN-C	0.861	0.796	3
Fe-N-C-P/N,P-C	0.87	0.80	4
Fe-Fe_3C@Fe-N-C	0.88	0.79	5
Fe-ISAs/CN	0.90	0.773	6
Fe-Zn-N-C	0.918	0.819	7
Fe,Mn/N-C	0.928	0.804	8
Fe/Ni-N_X/OC	0.938	0.84	9
Ce-Fe/NC	0.913	0.791	This work

Table S6. Comparison of the performance of primary or rechargeable ZABs containing various electrocatalysts as air electrodes in liquid electrolytes.

Catalysts materials	Power density ($mW\ cm^{-2}$)	Specific capacity ($mA\ h\ g^{-1}$)	Energy density ($W\ h\ kg^{-1}$)	Ref.
FeCo-IA/NC	115.6	635.3	725.6	10
PdMo bimetallene/C	154.2	798	1043	11
CoNi-SAs/NC	101.4	750.9	886.1	12
Co@SNHC	105.8	708		13
CoFe/N-HCSs	96.5	777.4	882.3	14
LCRO82	136	433		15
N-CoS_2 YSSs	81	744	922	16
Ni-N_4/GHSs/Fe-N_4		777.6	970.4	17
0.05CoO_X@NPC	157.3	887	1020	18
$S_{5.84\%}$-LCO	92	747		19
Ce-5.6%	60	783	963	20
Pt-SCFP/C-12	122	790.4		21
Pt/C	115	596	745	This work
Ce-Fe/NC	142	804	980	This work

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