Supplementary information

Aspects in Cell Design for H_2O_2 Electrosynthesis and Its Integration in Tandem Systems

Wenhao Chen[a], Chang Sun[a], and Wenchao Sheng[a,*]

[a]State Key Laboratory of Pollution Control and Resource Reuse,

College of Environmental Science and Engineering, Tongji University,

Shanghai Institute of Pollution Control and Ecological Security, Shanghai 200092, P. R. China

Email: wsheng@tongji.edu.cn

Table S1. Performance comparison of GDE reactor

GDE reactor	anodic reaction	co-generation of electricity	H_2O_2 production rate (mmol cm^{-2} h^{-1})	H_2O_2 Faradaic efficiency	stability	Ref
flow-cell	OER	No	3.3~6.1	85~95%	100~400 h	1-3
membrane-free flow-cell	OER	No	-	>90%	2 h	4
PEMFC	HOR	Yes	0.36~2.3	20~70%	80~120 h	5-7
AEMFC	HOR	Yes				n/a
SE-cell (CEM and AEM)	HOR	Yes	3.4~4.35	80~95%	100~500 h	1, 8, 9
SE-cell (CEM)	HOR	Yes	6.53	>90%	50 h	10
SE-cell (AEM)	HOR	Yes				n/a
Zn-Air battery	Zinc oxidation	Yes	0.593	85~92.5%	4~8 h	11, 12

Table S2. Summary of electrocatalyst performances in RRDE and GDE reactor from 2022 to 2024

(RRDE performances)

catalyst type	electrocatalyst	electrolyte	onset potential (V vs. RHE)	H_2O_2 selectivity	stability	Ref
metal-free carbon-based catalysts	N-C (2:3)	-	-	-	-	10
	PD/N-C	0.1 M $HClO_4$	0.6	＞90%@0.2~0.5 V	10 h@0.3 V	13
	BP2000	-	-	-	-	9
	SCN	0.1 M $HClO_4$	0.59	>70%@0~0.4 V	28 h@0.2 V	14
	SCN	0.1 M Na_2SO_4	0.5	>90%@ 0.1~0.4 V	28 h@0.2 V	
	MeCN	0.1 M KOH	0.85	>90%@0.2~0.8 V	9 h@0.5 V	15
	$MHCS_{0.5}$	0.1 M KOH	0.85	>90%@0.2~0.8 V	12 h@0.5 V	16
	$MHCS_{0.6}$	0.1 M PBS	0.6	>85%@0.1~0.5 V	12 h@0.5 V	
	BN-C/rGO	0.1 M KOH	0.78	>80%@0.35~0.75 V	12 h@0.4 V	17
	PBT	0.5 M KOH	0.77	>90%@0.45~0.75 V	12 h@0.6 V	18
	BS-C-3	0.1 M KOH	0.80	>90%@0.3~0.7 V	12 h@0.5 V	19
	CB-PDA-A	0.1 M KOH	0.83	>95%@0.4~0.7 V	12 h@0.5 V	20
	O-CDs-3	0.1 M KOH	0.7	>75%@0.2~0.5 V	-	21
	B/N-onion carbon	-	-	-	-	22
	N,S-TCNTs	0.1 M KOH	0.78	>90%@0.2~0.8 V	12 h@0.5 V	1
	BC-C-1	0.1 M KOH	0.79	>80%@0.45~0.75 V	10 h@0.4 V	23
	NBO-G/CNTs	0.1 M KOH	0.75	>80%@0.2~0.75 V	12 h@0.4 V	24
	E-BPC	0.1 M KOH	0.8	>80%@0.3~0.7 V	10 h@0.6 V	25
	VG array	-	-	-	-	26

	CNB-ZIL	0.1 M KOH	0.8	>70%@0~0.7 V	12 h@0.3 V	27
	CB	-	-	-	-	28
	g-C_3N_4/CNT	0.1 M KOH	0.8	>90%@0.1~0.6 V	10 h@0.5 V	29
	CB	0.2 Mm DTAB + 0.1 M KOH	0.7	>80%@0.1~0.6 V	-	30
	N,O-$CNS_{0.5}$	0.1 M K_2SO_4	0.65	>80%@0.1~0.6 V	12 h@0.3 V	31
	CBNO	0.1 M Na_2SO_4	0.55	>80%@0~0.6 V	10 h@0.1 V	32
	HCB(N/O)	0.1 M H_2SO_4	0.35	＞90%@0~0.3 V	12 h@0.25 V	33
	O-DG-30	0.1 M KOH	0.81	~80%@0.3~0.7 V	-	34
	COPN-3	0.1 M KOH	0.65	>90%@0~0.6 V	90 h@0.4 V	35
	N-CBMC-500	0.1 M KOH	0.7	>90%@0~0.6 V	10 h@0.4 V	36
	o-CNT-8	0.1 M KOH	0.795	>90%@0.4~0.7 V	-	37
	C-0.1M80	0.1 M KOH	0.795	>80%@0.2~0.6 V	-	38
non-precious metal catalysts	$CoSe_{2-x}$-1	0.1 M $HClO_4$	0.73	>80%@0.2~0.6 V	-	39
	CoIn-N-C	0.1 M $HClO_4$	0.78	>80%@0.4~0.7 V	-	40
	CoPc-OCNT	-	-	-	-	41
	p–Co–N–C	0.5 M H_2SO_4	0.65	>80%@0~0.6 V	-	42
	CoN_4/VG	-	-	-	-	43
	Co-N-C/$Ti_3C_2T_x$	0.5 M H_2SO_4	0.72	>60%@0.2~0.7 V	-	44
	Co-N SAC_{Dp}	0.1 M $HClO_4$	0.65	>90%@0.1~0.6 V	5.5 h@0.25 V	45
	Co_2-DAC	0.1 M $HClO_4$	0.72	>90%@0.1~0.6 V	12 h@0.3 V	2
	CoTPP@RGO-160	0.5 M H_2SO_4	0.6	>90%@0.1~0.4 V	8 h@0.1 V	46
	ZnO@ZnO_2	0.1 M K_2SO_4	0.5	~100%@0~0.4 V	40 h@0.1 V	47
	h-SnO_2	0.1 M Na_2SO_4	0.48	>95%@0~0.4 V	-	48
	ZnO/rGO	-	-	-	-	49

	P-hcp Ni	0.1 M Na_2SO_4	0.42	>95%@0~0.2 V	9 h@0.2 V	50
	ZnO-v	0.6 M K_2SO_4	0.43	>80%@0.1~0.4 V	-	51
	L-ZnO	0.6 M K_2SO_4	0.35	>80%@0.05~0.35 V	-	52
	Co_1-NBC	0.1 M $HClO_4$	0.724	~90%@0.2~0.6 V	10 h@0.35 V	53
	CoN_4C-N	0.1 M $HClO_4$	0.72	>80%@0.1~0.6 V	-	54
	Co-N_3O	0.1 M KOH	0.8	~90%@0.1~0.6 V	-	55
	Ni-N_3S	0.1 M KOH	0.8	~90%@0.1~0.6 V	-	
	TiO_2@Ti_2O_3	0.1 M KOH	0.78	>80%@0.1~0.6 V	12 h@0.2 V	56
	CoPorF/CNT	0.1 M $HClO_4$	0.62	~90%@0.2~0.5 V	-	57
	Mn CD/C	0.1 M KOH	0.786	>90%@0.2~0.7 V	10 h@0.5 V	58
	F/Co-N-G	0.1 M KOH	0.81	>80%@0.1~0.8 V	10 h@0.1 V	59
	E-Niln	0.1 M KOH	0.72	>90%@0.1~0.6 V	24 h@0.55 V	60
	CoPc-S-COF	0.1 M KOH	0.8	>80%@0.2~0.7 V	10 h@0.52 V	61
	Pb SA/OSC	0.1 M KOH	0.76	>90%@0.3~0.7 V	-	62
Precious metal catalysts	a-$PdSe_2$ NP/C	0.1 M $HClO_4$	0.57	>90%@0~0.3 V	10 h@0 V	63
	Pt-N-CNT-Gly	0.1 M $HClO_4$	0.45	>80%@0.05~0.45 V	14 h@0.3 V	64
	Se_2-Pt	0.1 M $HClO_4$	0.7	>95%@0~0.6 V	15 h@0 V	3
	$PdSe_2$	0.05 M NaPi	0.6	>60%@0~0.6 V	-	65
	Pd/MCS-8	0.1 M K_2SO_4	0.65	>90%@0.1~0.6 V	12 h@0.3 V	66
	Pd SNCs/$NiTe_2$	0.1 M KOH	0.81	>80%@0.3~0.6 V	20 h@0.4 V	67

Table S3. Summary of electrocatalyst performances in RRDE and GDE reactor from 2022 to 2024

(Reactor performances)

catalyst type	electrocatalyst	GDE reactor	electrolyte	current density (mA cm^{-2})	H_2O_2 production rate (mmol cm^{-2} h^{-1})	H_2O_2 Faradaic efficiency	stability	Ref
metal-free carbon-based catalysts	N-C (2:3)	CEM-SE-cell	pure water	389@2.35 V	6.53@2.35 V	>90%	50 h@70 mA cm^{-2}	10
	PD/N-C	flow-cell	0.1 M $HClO_4$	38@-0.6 V	-	~98%	144 h@-0.6 V	13
	BP2000	flow-cell	0.1 M H_2SO_4 + 0.05 M Na_2SO_4	400@-0.9 V	6.5@-0.9 V	>80%	20 h@200 mA cm^{-2}	9
	BP2000	MEA(ORR-OER)	0.1 M H_2SO_4 + 0.05 M Na_2SO_4	70 @1.7 V	-	~10%	-	
	BP2000	double-PEM SE	0.03 M Na_2SO_4	50@1.85 V	-	~90%	500 h@50 mA cm^{-2}	
	SCN	flow-cell	0.1 M HClO4	100@-0.8 V	1.3@100 mA cm^{-2}	~70%	168 h@100 mA cm^{-2}	14
	SCN	flow-cell	1 M Na_2SO_4	100@0 V	1.65@100 mA cm^{-2}	~90%	168 h@100 mA cm^{-2}	
	MeCN	flow-cell	0.1 M KOH	200@0.2 V	3.6@0.2 V	>90%	24 h@0.2 V	15
	$MHCS_{0.5}$	flow-cell	0.1 M KOH	250@0.1 V	4.3@0.1 V	>90%	16 h@0.1 V	16
	$MHCS_{0.6}$	flow-cell	0.1 M PBS	175@0.1 V	3.16@0.1 V	>90%	16 h@0.1 V	
	BN-C/rGO	flow-cell	0.1 M KOH	50@0.2 V	0.96@0.2 V	70~100%	8 h@0.2 V	17
	PBT	flow-cell	1.0 M KOH	100@0.4 V	1.88@100 mA cm^{-2}	>80%	50 h@100 mA cm^{-2}	18

BS-C-3	flow-cell	0.1 M KOH	50@0.2 V	0.75@50 mA cm^{-2}	>90%	11 h@0.2 V	19
CB-PDA-A	flow-cell	0.1 M KOH	60@1.5 V	0.54@1.5 V	>90%	250 h@1.5 V	20
O-CDs-3	flow-cell	0.1 M KOH + 10 Mm EDTA	-	-	>70%	10 h@10 mA cm^{-2}	21
B/N-onion carbon	flow-cell	1 M KOH	100@0.4 V	1.75@0.4 V	>95%	12 h@0.2 V	22
N,S-TCNTs	flow-cell	1 M KOH	300@0.5 V	6.07@350 mA cm^{-2}	~95%	200 h@32 mA cm^{-2}	1
N,S-TCNTs	SE cell	pure water	300@2.7 V	4.35@300 mA cm^{-2}	~70%	300 h@20 mA cm^{-2}	
BC-C-1	flow-cell	1 M KOH	50@0.3 V	0.76@0.3 V	>75%	12 h@0.3 V	23
NBO-G/CNTs	flow-cell	1 M KOH	50@0.2 V	0.71@0.2 V	80~50%	12 h@0.2 V	24
E-BPC	flow-cell	1 M KOH	300@0.67 V	4.7@300 mA cm^{-2}	>80%	100 h@100 mA cm^{-2}	25
E-BPC	flow-cell	1 M Na_2SO_4	300@0.27 V	4.76@300 mA cm^{-2}	>80%	24 h@100 mA cm^{-2}	
VG array	flow-cell	0.1 M KOH	100@0.4 V	1.80@100 mA cm^{-2}	~90%	16 h@100 mA cm^{-2}	26
CNB-ZIL	flow-cell	0.1 M KOH	50@1.4 V	-	~80%	9 h@1.4 V	27
CB	flow-cell	0.1 M $NaClO_4$	-	0.57@28 mA cm^{-2}	>80%		28
g-C_3N_4/CNT	flow-cell	1 M KOH	100@0.37 V	-	>90%	8 h@100 mA cm^{-2}	29
CB	flow-cell	0.2 Mm DTAB + 0.1 M KOH	10@0.2 V	-	~90%	30 h@0.2 V	30
N,O-$CNS_{0.5}$	flow-cell	0.1 M K_2SO_4	100@0.2 V	1.67@0.2 V	>90%	24 h@0.2 V	31
CBNO	flow-cell	1 M Na_2SO_4	100@-0.4 V	1.34@100 mA cm-2	>90%	24 h@100 mA cm^{-2}	32

	HCB(N/O)	flow-cell	0.1 M H_2SO_4	31@-0.5 V	-	~90%	80 h@-0.5 V	33
	O-DG-30	flow-cell	0.1 M KOH	35@0.50 V	0.59@0.50 V	>95%	10 h@0.5 V	34
	COPN-3	flow-cell	1 M KOH	-	1.76@130 mA cm^{-2}	~70%	-	35
			0.5 M Na_2SO_4	130@-2 V	2.57@130 mA cm^{-2}	~100%	70 h@130 mA cm^{-2}	
			0.5 M H_2SO_4	-	0.66@130 mA cm-2	~25%	-	
	N-CBMC-500	flow-cell	1 M KOH	-	0.42@-1.2 V	~60%	-	36
			0.5 M Na_2SO_4	-	0.49@-0.65 V	~70%	-	
			0.5 M H_2SO_4	-	0.24@-0.9 V	~30%	-	
	o-CNT-8	SE-cell	pure water	93@4 V	1.59@4 V	~92%	100 h@4 V	37
	C-0.1M80	SE-cell (HOR-$2e^-$ ORR)	pure water	100@1 V	1.79@100 mA cm^{-2}	95.8%	200 h@100 mA cm-2	38
non-precious metal catalysts	$CoSe_{2-x}$-1	flow-cell	0.1 M $HClO_4$	10@0 V	-	70%	32 h@0 V	39
	CoIn-N-C	flow-cell	0.1 M $HClO_4$	100@0.2 V	1.94@100 mA cm^{-2}	~80%	4 h@100 mA cm^{-2}	40
	CoPc-OCNT	flow-cell	0.3 M K_2SO_4 (pH=1.5)	-	5.75@300 mA cm^{-2}	~100%	-	41
	p–Co–N–C	flow-cell	0.5 M H_2SO_4	35@0 V	-	>80%	4 h@0.1 V	42
	CoN_4/VG	flow-cell	0.1 M $HClO_4$	24@1.8 V	0.304 @1.8 V	~70%	6 h@1.8 V	43
	Co-N-C/$Ti_3C_2T_x$	flow-cell	0.5 M H_2SO_4	75@0.1 V	2.8@0.1 V	~75	20 h@0.1 V	44
	Co-N SAC_{Dp}	flow-cell	0.1 M $HClO_4$	50@0 V	0.78@ 50 mA cm^{-2}	>70%	90 h@0.1 V	45
	Co_2-DAC	flow-cell	0.1 M $HClO_4$	50@0 V	0.85@50 mA cm^{-2}	~90%	100 h@50 mA cm^{-2}	2
				200@-0.8 V	3.3@200 mA cm^{-2}	~85%	100 h@200 mA cm^{-2}	

CoTPP@RGO-160	flow-cell	0.5 M H_2SO_4	200@-0.6 V	3.1@200 mA cm^{-2}	>80%	16 h@200 mA cm^{-2}	46
	PEMWE (OER-2e^- ORR)	pure water	400@2.1 V	-	-	225 h@ 400 mA cm^{-2}	
ZnO@ZnO_2	flow-cell	0.1 M K_2SO_4	125@0.1 V	2.2@0.1V	~95%	50 h@0.1 V	47
h-SnO_2	flow-cell	1M Na_2SO_4	124@0 V	2.06@0 V	~90%	40 h@120 mA cm^{-2}	48
h-SnO_2	flow-cell	pure water	100@0 V	-	-	20 h@0 V	
ZnO/rGO	flow-cell	0.6 M K_2SO_4	500@-0.8 V	9.7@-0.8 V	~90%	24 h@200 mA cm^{-2}	49
ZnO/rGO	tandem-parallel flow-cell	0.6 M K_2SO_4	455@-0.8 V	8.73@-0.8 V	~90%	24 h@100 mA cm^{-2}	
P-hcp Ni	flow-cell	pure water	150@-1 V	2.42@150 mA cm^{-2}	~90%	120 h@-1 V	50
		sea water	180@-1 V	2.5 @-1 V	~90%	3 h@-1 V	
		pure water	150@-0.6 V	2.44@150 mA cm^{-2}	~90%	130 h@150 mA cm^{-2}	
ZnO-v	flow-cell	0.6 M K_2SO_4	-	18.3@1000 mA cm^{-2}	>95%	20 h@200 mA cm^{-2}	51
L-ZnO	flow-cell	0.6 M K_2SO_4	-	18.2@1000 mA cm^{-2}	~95%	20 h@200 mA cm^{-2}	52
Co_1-NBC	flow-cell	0.5 M H_2SO_4	350@-0.5 V	5.96@350 mA cm^{-2}	~86%	60 h@200 mA cm^{-2}	53
CoN_4C-N	flow-cell	0.1 M $HClO_4$	10@0.358 V	0.096@0.358 V	~82%	200 h@0.358 V	54
Co-N_3O	flow-cell	1 M KOH	110@0.1 V	1.42@0.1 V	~90%	12 h@0.1 V	55

	Ni-N_3S	flow-cell	1 M KOH	110@0.2 V	1.75@0.2 V	~90%	12 h@0.2 V	
	TiO_2@Ti_2O_3	SE-cell	pure water	200@2.5 V	-	>80%	100 h@2.28 V	56
	CoPorF/CNT	SE-cell	pure water	50@2.7 V	5.38@3.02 V	~80%	48 h@50 mA cm^{-2}	57
	Mn CD/C	flow-cell	1 M KOH	200@0.5 V	-	~80%	50 h@200 mA cm^{-2}	58
	F/Co-N-G	flow-cell	1 M KOH	70@0.3 V	1.21@0.3 V	~70%	80 h@0.3 V	59
	E-Niln	flow-cell	0.1 M KOH	200@0.4 V	2.4@0.4 V	~90%	20 h@200 mA cm^{-2}	60
	CoPc-S-COF	flow-cell	1 M KOH	125@0.67 V	-	~90%	20 h@125 mA cm^{-2}	61
	Pb SA/OSC	flow-cell	1 M KOH	-	6.9@400 mA cm^{-2}	93%	100 h@50 mA cm^{-2}	62
Precious metal catalysts	a-$PdSe_2$ NP/C	flow-cell	0.1 M $HClO_4$	50@-0.5 V	0.70@0 V	>80%	2 h@50 mA cm^{-2}	63
	Pt-N-CNT-Gly	flow-cell	0.05 M H_2SO_4 + 0.05 M Na_2SO_4	100@-0.2 V	-	~85%	30 h@100 mA cm^{-2}	64
	Se_2-Pt	flow-cell	0.1 M $HClO_4$	250@3 V	4.16@250 mA cm^{-2}	~90%	400 h@250 mA cm^{-2}	3
	$PdSe_2$	flow-cell	0.5 M NaPi	5.5@0.3 V	0.00356@5.5 mA cm^{-2}	~30%	3 h@5.5 mA cm^{-2}	65
	Pd/MCS-8	flow-cell	0.5 M K_2SO_4	250@0.2 V	3.94@0.2 V	>86%	24 h@0.2 V	66
	Pd SNCs/$NiTe_2$	flow-cell	0.1 M KOH	100@0 V	1.75@100 mA cm^{-2}	95%	10 h@0 V	67

Table S4. Summary of $2e^-$ ORR integrated tandem systems from 2022 to 2024

electro-catalyst	thermo-catalyst	reactor	tandem mode	electrolyte	H_2O_2 Faradaic efficiency	tandem application	performance	stability	Ref
CNT-NH_2	TS-1	SE-cell	ex-cell	pure water	~80%@200 mA cm^{-2}	oxidation of ethylene	2.2 mmol h^{-1} and 70% FE of ethylene glycol	100 h@30 mA cm^{-2}	68
carbon nanofibres	-	SE-cell	ex-cell	pure water	-	oxidation of nitrogen	5.84 nmol s^{-1} and 25% FE of nitrates	-	69
nitric-acid-treated carbon black	TS-1	SE-cell	ex-cell	pure water	98.1%@-147.1 mA cm^{-2}	synthesize of glycine	3.61 mmol g^{-1} h^{-1} of glycine	100 h@10 mA cm^{-2}	70

F-CB	TS-1	SE-cell	in-cell	0.1 M K_2SO_4	~80%@37.5 mA cm^{-2}	oxidation of phenol	30.25% FE and 94.68% selectivity of catechol and hydroquinone	18 h@37.5 mA cm^{-2}	71
C-acid	MIL-53 (Al, Fe)	PEMFC	in-cell	pure water	~80%@-0.1~0 V	oxidation of propane	2.65 μmol h^{-1} cm^{-2} of C_3 products	10 h@-0.2 V	72
C–O	TS-1	flow-cell	in-cell	0.1 M H_2SO_4	-	oxidation of propylene	4.28 mmol g^{-1} h^{-1} and 79.7% selectivity of propylene glycol	-	73
a-KB	-	H-cell	in-cell	0.05 M H_2SO_4	~90%@0.3~0 V	oxidation of methane	80.7% selectivity of formic acid	6 h@0 V	74
MC-3	TS-1	flow-cell	in-cell	0.1M NaPi (pH=10)	~90%@0.4~0.6 V	oxidation of ethylene	51.48 mmol g^{-1} h^{-1} of ethylene glycol	50 h@-4 mA cm^{-2}	75
CB	TS-1	SE-cell	in-cell	pure water	>80%@50 mA cm^{-2}	oxidation of ethylene	99.7% selectivity of ethylene glycol	200 h@10 mA cm^{-2}	76
PDC@VG	-	flow-cell	in-cell	0.5 M H_2SO_4 + 0.5 M $C_2H_4O_2$	>80%@0.2~0.4 V	oxidation of acetic acid	58.5 μmol cm^{-2} h^{-1} of peracetic acid	7 h@-1.6 V	77
CB	-	flow-cell	in-cell	1 mol L^{-1} HCOOH/CHOOK + 1 wt% H_3PO_4	-	oxidation of formic acid	24% conversion of performic acid	6 h@100 mA cm^{-2}	78

CB-3	Ti-MOR	flow-cell	in-cell	1 M NH_4HCO_3	~80%@0.4~0.7 V	ammoxidations of cyclohexanone	96% FE and 99% selectivity of cyclohexanone oxime	45 h@0.1 V	79
Co–N–C	TS-1	H-cell	in-cell	0.5 M H_2SO_4	>90%@0.1~0.3 V	oxidation of phenol	30.05% FE and 99.45% selectivity of bisphenol	-	80
Mg3(HHTP)$_2$	TS-1	flow-cell	in-cell	pure water	~90%@1.6~2.6 V	oxidation of propylene	99% selectivity of propylene oxide	8 h@20 mA cm^{-2}	81
FeSAs/ACs-BCC	-	H-cell	in-cell	0.1 M Na_2SO_4 (pH~2.43) + 10 mM EG + 1 mM Fe^{2+}	>90%@0.2~0.7 V	oxidation of ethylene glycol	86.2% selectivity of formic acid	-	82
Co-O-C	-	flow-cell	in-cell	0.1 M $KHCO_3$ + 0.05 M KNO_3	>70%@0.3~0.6 V	oxidation of urea	4648.2 μg h^{-1} mg^{-1} and 53% FE of urea peroxide	-	83
Mn-NO-C_H	-	flow-cell	in-cell	1 M KOH	>80%@0~0.6 V	hydration of benzonitrile	100% conversion of benzonitrile	55 h@0.1 V	84
Ag foil	-	H-cell	in-cell	0.1 M $HClO_4$ + 2 mM Fe^{2+}	~90%@0.2 V	oxidation of methane	11.5 mmol h^{-1} g_{Fe}^{-1} and 81.4% FE of formic acid	8 h@0.2 V	85
CoPorF/CNT	-	flow-cell	in-cell	pure water	>90%@0.2~0.5 V	hydroxylation of phenol	94.7% selectivity of dihydroxy benzene	48 h@ 50 mA cm^{-2}	57
B/N-onion carbon	-	flow-cell	in-cell	1 M KOH	>80%@0.2~0.7 V	synthesize of sodium peroxyborate and dibenzoyl peroxide	-	10 h@0.7 V	86
c-$NiSe_2$/CFP	-	H-cell	in-cell	0.1 M $NaHSO_4$/Na_2S	>60%@0~0.6 V	oxidation of glycerol	55% conversion of C_3 products	37 h@0.6 V	87

				O_4 (pH ~2.8)					
T-NiOC	-	flow-cell	in-cell	0.4 M NaOH + saturated $Ca(OH)_2$	-	synthesis of alkaline-earth metal peroxides	99% selectivity of calcium peroxide	1000 h@50 mA cm^{-2}	88
graphite rod	-	H-cell	in-cell	0.25 M $LiSO_4/H_2SO_4$ (pH=3) with 1 Mm Fe^{2+}	-	oxidation of nitrogen	141.83 μmol h^{-1} g^{-1} and 25.37% FE of nitrates	10 h@0 V	89

References:

1. Y. Long, J. Lin, F. Ye, W. Liu, D. Wang, Q. Cheng, R. Paul, D. Cheng, B. Mao, R. Yan, L. Zhao, D. Liu, F. Liu and C. Hu, *Advanced Materials*, 2023, **35**, 2303905.
2. H. Huang, M. Sun, S. Li, S. Zhang, Y. Lee, Z. Li, J. Fang, C. Chen, Y.-X. Zhang, Y. Wu, Y. Che, S. Qian, W. Zhu, C. Tang, Z. Zhuang, L. Zhang and Z. Niu, *Journal of the American Chemical Society*, 2024, **146**, 9434-9443.
3. Z. Yu, H. Deng, Q. Yao, L. Zhao, F. Xue, T. He, Z. Hu, W.-H. Huang, C.-W. Pao, L.-M. Yang and X. Huang, *Nature Communications*, 2024, **15**, 9346.
4. Z. Chen, S. Chen, S. Siahrostami, P. Chakthranont, C. Hahn, D. Nordlund, S. Dimosthenis, J. K. Nørskov, Z. Bao and T. F. Jaramillo, *Reaction Chemistry & Engineering*, 2017, **2**, 239-245.
5. J. Yang, R. Ding, C. Liu, Q. Xu, S. Liu and X. Yin, *Journal of Physics: Energy*, 2024, **6**, 015022.
6. H. Li, P. Wen, D. S. Itanze, Z. D. Hood, S. Adhikari, C. Lu, X. Ma, C. Dun, L. Jiang, D. L. Carroll, Y. Qiu and S. M. Geyer, *Nature Communications*, 2020, **11**, 3928.
7. H. Zou, L. J. Arachchige, H. Dai, H. Liu, F. Jiao, W. Hu, F. Li, S. Wei, C. Sun and L. Duan, *Chem Catalysis*, 2023, **3**, 100583.
8. C. Xia, Y. Xia, P. Zhu, L. Fan and H. Wang, *Science*, 2019, **366**, 226-231.
9. X. Zhang, X. Zhao, P. Zhu, Z. Adler, Z.-Y. Wu, Y. Liu and H. Wang, *Nature Communications*, 2022, **13**, 2880.
10. B. Sabri Rawah, M. Albloushi and W. Li, *Chemical Engineering Journal*, 2023, **466**, 143282.
11. R. Xie, C. Cheng, R. Wang, J. Li, E. Zhao, Y. Zhao, Y. Liu, J. Guo, P. Yin and T. Ling, *ACS Catalysis*, 2024, **14**, 4471-4477.
12. W. Wang, Y. Hu, Y. Liu, Z. Zheng and S. Chen, *ACS Applied Materials & Interfaces*, 2018, **10**, 31855-31859.
13. C. Zhang, W. Shen, K. Guo, M. Xiong, J. Zhang and X. Lu, *Journal of the American Chemical Society*, 2023, **145**, 11589-11598.
14. Z. Mou, Y. Mu, L. Liu, D. Cao, S. Chen, W. Yan, H. Zhou, T.-S. Chan, L.-Y. Chang and X. Fan, *Small*, 2024, **20**, 2400564.
15. Q. Tian, L. Jing, Y. Yin, Z. Liang, H. Du, L. Yang, X. Cheng, D. Zuo, C. Tang, Z. Liu, J. Liu, J. Wan and J. Yang, *Nano Lett*, 2024, **24**, 1650-1659.
16. Q. Tian, L. Jing, H. Du, Y. Yin, X. Cheng, J. Xu, J. Chen, Z. Liu, J. Wan, J. Liu and J. Yang, *Nature Communications*, 2024, **15**, 983.
17. Q. Yuan, M. Fan, Y. Zhao, J. Wu, J. Raj, Z. Wang, A. Wang, H. Sun, X. Xu, Y. Wu, K. Sun and J. Jiang, *Applied Catalysis B: Environmental*, 2023, **324**, 122195.
18. Z. Yang, Y. Gao, L. Zuo, C. Long, C. Yang and X. Zhang, *ACS Catalysis*, 2023, **13**, 4790-4798.
19. Y. Wu, Q. Yuan, Y. Zhao, X. Xu, J. Xu, Y. Wang, K. Sun, A. Wang, H. Sun, B. Li, R. Xu, Z. Wang, J. Jiang and M. Fan, *ACS Sustainable Chemistry & Engineering*, 2023, **11**, 13363-13373.
20. J. Su, L. Jiang, B. Xiao, Z. Liu, H. Wang, Y. Zhu, J. Wang and X. Zhu, *Small*, 2024, **20**, 2310317.
21. X. Shen, Z. Wang, H. Guo, Z. Lei, Z. Liu and L. Wang, *Small*, 2023, **19**, 2303156.

22. B. Qiu, M. Liu, X. Qu, F. Zhou, H. Xie, D. Wang, L. Y. S. Lee and H. Yin, *Nature Communications*, 2024, **15**, 6473.
23. M. Fan, Z. Wang, Y. Zhao, Q. Yuan, J. Cui, J. Raj, K. Sun, A. Wang, J. Wu, H. Sun, B. Li, L. Wang and J. Jiang, *Carbon Energy*, 2023, **5**, e309.
24. M. Fan, Z. Wang, K. Sun, A. Wang, Y. Zhao, Q. Yuan, R. Wang, J. Raj, J. Wu, J. Jiang and L. Wang, *Advanced Materials*, 2023, **35**, 2209086.
25. A. Byeon, J. W. Choi, H. W. Lee, W. C. Yun, W. Zhang, C.-K. Hwang, S. Y. Lee, S. S. Han, J. M. Kim and J. W. Lee, *Applied Catalysis B: Environmental*, 2023, **329**, 122557.
26. Y. Wang, R. Shi, L. Shang, L. Peng, D. Chu, Z. Han, G. I. N. Waterhouse, R. Zhang and T. Zhang, *Nano Energy*, 2022, **96**, 107046.
27. Z. Tian, Q. Zhang, L. Thomsen, N. Gao, J. Pan, R. Daiyan, J. Yun, J. Brandt, N. López-Salas, F. Lai, Q. Li, T. Liu, R. Amal, X. Lu and M. Antonietti, *Angewandte Chemie International Edition*, 2022, **61**, e202206915.
28. H. Li, E. Quispe-Cardenas, S. Yang, L. Yin and Y. Yang, *ACS ES&T Engineering*, 2022, **2**, 242-250.
29. J. Qu, G. Long, L. Luo, Y. Yang, W. Fan and F. Zhang, *Small*, 2024, **20**, 2400695.
30. Y. Fan, Y. Chen, W. Ge, L. Dong, Y. Qi, C. Lian, X. Zhou, H. Liu, Z. Liu, H. Jiang and C. Li, *Journal of the American Chemical Society*, 2024, **146**, 7575-7583.
31. L. Jing, Q. Tian, W. Wang, X. Li, Q. Hu, H. Yang and C. He, *Advanced Energy Materials*, 2024, **14**, 2304418.
32. Z. Song, X. Chi, S. Dong, B. Meng, X. Yu, X. Liu, Y. Zhou and J. Wang, *Angewandte Chemie International Edition*, 2024, **63**, e202317267.
33. Y. Wang, B. Li, G. Chen, Y. Wu, M. Tian, Y. Peng, S. Dou, L. Li and J. Sun, *Environmental Science & Technology*, 2024, DOI: 10.1021/acs.est.4c11612.
34. Q. Wu, H. Zou, X. Mao, J. He, Y. Shi, S. Chen, X. Yan, L. Wu, C. Lang, B. Zhang, L. Song, X. Wang, A. Du, Q. Li, Y. Jia, J. Chen and X. Yao, *Nature Communications*, 2023, **14**, 6275.
35. Z. Bao, Q. Cao, Y. Shao, S. Zhang, X. Peng, Y. Li, C. Jiang, X. Zhong and J. Wang, *ACS Catalysis*, 2023, **13**, 14492-14502.
36. Z. Bao, J. Zhao, S. Zhang, L. Ding, X. Peng, G. Wang, Z. Zhao, X. Zhong, Z. Yao and J. Wang, *Journal of Materials Chemistry A*, 2022, **10**, 4749-4757.
37. F. She, Z. Guo, F. Liu, Z. Yu, J. Chen, Y. Fan, Y. Lei, Y. Chen, H. Li and L. Wei, *ACS Catalysis*, 2024, **14**, 10928-10938.
38. S. Jia, H. Yu, J. Na, Z. Liu, K. Lv, Z. Ren, S. Sun and Z. Shao, *ACS Applied Materials & Interfaces*, 2024, **16**, 23099-23108.
39. C.-D. Han, Y.-C. Zhang, Q. Zhang, J.-T. Wu, J. Gao, J.-J. Zou and X.-D. Zhu, *Rare Metals*, 2024, **43**, 500-510.
40. J. Du, G. Han, W. Zhang, L. Li, Y. Yan, Y. Shi, X. Zhang, L. Geng, Z. Wang, Y. Xiong, G. Yin and C. Du, *Nature Communications*, 2023, **14**, 4766.
41. P. Cao, X. Quan, X. Nie, K. Zhao, Y. Liu, S. Chen, H. Yu and J. G. Chen, *Nature Communications*, 2023, **14**, 172.
42. J. Zhang, W. Liu, F. He, M. Song, X. Huang, T. Shen, J. Li, C. Zhang, J. Zhang and D. Wang, *Chemical Engineering Journal*, 2022, **438**, 135619.
43. Z. Lin, Q. Zhang, J. Pan, C. Tsounis, A. A. Esmailpour, S. Xi, H. Y. Yang, Z. Han, J. Yun, R. Amal and X. Lu, *Energy & Environmental Science*, 2022, **15**, 1172-1182.
44. X. Huang, W. Liu, J. Zhang, M. Song, C. Zhang, J. Li, J. Zhang and D. Wang, *ACS Applied Materials & Interfaces*, 2022, **14**, 11350-11358.

45. S. Chen, T. Luo, K. Chen, Y. Lin, J. Fu, K. Liu, C. Cai, Q. Wang, H. Li, X. Li, J. Hu, H. Li, M. Zhu and M. Liu, *Angewandte Chemie International Edition*, 2021, **60**, 16607-16614.
46. Y. Chen, C. Zhen, Y. Chen, H. Zhao, Y. Wang, Z. Yue, Q. Wang, J. Li, M. D. Gu, Q. Cheng and H. Yang, *Angewandte Chemie International Edition*, 2024, **63**, e202407163.
47. Y. Zhou, L. Xu, J. Wu, W. Zhu, T. He, H. Yang, H. Huang, T. Cheng, Y. Liu and Z. Kang, *Energy & Environmental Science*, 2023, **16**, 3526-3533.
48. Y. Zhang, M. Wang, W. Zhu, M. Fang, M. Ma, F. Liao, H. Yang, T. Cheng, C.-W. Pao, Y.-C. Chang, Z. Hu, Q. Shao, M. Shao and Z. Kang, *Angewandte Chemie International Edition*, 2023, **62**, e202218924.
49. B. Xia, Q. Huang, H. Wang, L. Yu, S. Ding, L. Jiang, M. Li, J. Duan and S. Chen, *ACS Applied Materials & Interfaces*, 2023, **15**, 32416-32424.
50. S. Geng, Y. Ji, S. Yang, J. Su, Z. Hu, T.-S. Chan, H. Yu, Y. Li, Y.-Y. Chin, X. Huang and Q. Shao, *Advanced Functional Materials*, 2023, **33**, 2300636.
51. S. Ding, Y. Zhang, F. Lou, M. Li, Q. Huang, K. Yang, B. Xia, C. Tang, J. Duan, M. Antonietti and S. Chen, *Materials Today Energy*, 2023, **38**, 101430.
52. S. Ding, B. Xia, M. Li, F. Lou, C. Cheng, T. Gao, Y. Zhang, K. Yang, L. Jiang, Z. Nie, H. Guan, J. Duan and S. Chen, *Energy & Environmental Science*, 2023, **16**, 3363-3372.
53. S. Chen, T. Luo, J. Wang, J. Xiang, X. Li, C. Ma, C.-w. Kao, T.-S. Chan, Y.-N. Liu and M. Liu, *Angewandte Chemie International Edition*, 2024, **n/a**, e202418713.
54. W. Wang, Y. Hu, P. Li, Y. Liu and S. Chen, *ACS Catalysis*, 2024, **14**, 5961-5971.
55. W. Liu, R. Chen, Z. Sang, Z. Li, J. Nie, L. Yin, F. Hou and J. Liang, *Advanced Materials*, 2024, **36**, 2406403.
56. Y. Yao, H. Wang, K. Dong, H. Li, J. Liang, R. Li, S. Sun, Z. Cai, X. He, D. Zheng, Y. Luo, S. Alfaifi, D. Ma, W. Hu and X. Sun, *Journal of Materials Chemistry A*, 2023, **11**, 22154-22160.
57. C. Liu, Z. Yu, F. She, J. Chen, F. Liu, J. Qu, J. M. Cairney, C. Wu, K. Liu, W. Yang, H. Zheng, Y. Chen, H. Li and L. Wei, *Energy & Environmental Science*, 2023, **16**, 446-459.
58. Y. Zeng, X. Tan, Z. Zhuang, C. Chen and Q. Peng, *Angewandte Chemie International Edition*, 2024, **n/a**, e202416715.
59. H. Gong, Z. Gong, J. Liu, G. Ye and H. Fei, *Advanced Functional Materials*, 2024, **34**, 2316438.
60. K. Yu, H. Yang, J. Xu, W. Yuan, R. Yang, M. Hou, Z. Kang, Y. Liu, P. W. Menezes and Z. Chen, *Angewandte Chemie International Edition*, 2024, **63**, e202408508.
61. Q. Zhi, R. Jiang, X. Yang, Y. Jin, D. Qi, K. Wang, Y. Liu and J. Jiang, *Nature Communications*, 2024, **15**, 678.
62. X. Zhou, Y. Min, C. Zhao, C. Chen, M.-K. Ke, S.-L. Xu, J.-J. Chen, Y. Wu and H.-Q. Yu, *Nature Communications*, 2024, **15**, 193.
63. Z. Yu, S. Lv, Q. Yao, N. Fang, Y. Xu, Q. Shao, C.-W. Pao, J.-F. Lee, G. Li, L.-M. Yang and X. Huang, *Advanced Materials*, 2023, **35**, 2208101.
64. B. Ni, P. Shen, G. Zhang, J. Zhao, H. Ding, Y. Ye, Z. Yue, H. Yang, H. Wei and K. Jiang, *Journal of the American Chemical Society*, 2024, **146**, 11181-11192.

65. R. D. Ross, K. Lee, G. J. Quintana Cintrón, K. Xu, H. Sheng, J. R. Schmidt and S. Jin, *Journal of the American Chemical Society*, 2024, **146**, 15718-15729.
66. L. Jing, W. Wang, Q. Tian, Y. Kong, X. Ye, H. Yang, Q. Hu and C. He, *Angewandte Chemie International Edition*, 2024, **63**, e202403023.
67. Y. Li, Y. Liu, X. Peng, Z. Zhao, Z. Li, B. Yang, Q. Zhang, L. Lei, L. Dai and Y. Hou, *Angewandte Chemie International Edition*, 2024, **n/a**, e202413159.
68. L. Fan, Y. Zhao, L. Chen, J. Chen, J. Chen, H. Yang, Y. Xiao, T. Zhang, J. Chen and L. Wang, *Nature Catalysis*, 2023, **6**, 585-595.
69. K. Dong, Y. Yao, H. Li, H. Li, S. Sun, X. He, Y. Wang, Y. Luo, D. Zheng, Q. Liu, Q. Li, D. Ma, X. Sun and B. Tang, *Nature Synthesis*, 2024, **3**, 763-773.
70. X. Kong, C. Liu, Z. Xu, J. Zhao, J. Ni, H. Li, T. Zheng, C. Xia, Z. Geng and J. Zeng, *Angewandte Chemie International Edition*, 2024, **63**, e202411160.
71. H. Zhang, S. Wu, X. Huang, L. Li, Q. Liao and Z. Wei, *Chemical Engineering Journal*, 2022, **428**, 131534.
72. C.-H. Yang, X.-C. Liu, Y. Li, S. Yuan, T. Wang, Z.-Y. Zhou and S.-G. Sun, *ChemSusChem*, 2023, **16**, e202300699.
73. X.-C. Liu, W.-K. Yao, B.-Y. Su, Y.-H. Hong, T. Wang, Z.-Y. Zhou and S.-G. Sun, *Electrochemistry Communications*, 2023, **151**, 107510.
74. J. Kim, J. H. Kim, C. Oh, H. Yun, E. Lee, H.-S. Oh, J. H. Park and Y. J. Hwang, *Nature Communications*, 2023, **14**, 4704.
75. M.-H. Guan, L.-Y. Dong, T. Wu, W.-C. Li, G.-P. Hao and A.-H. Lu, *Angewandte Chemie International Edition*, 2023, **62**, e202302466.
76. S.-K. Zhang, Y. Feng, A. Elgazzar, Y. Xia, C. Qiu, Z. Adler, C. Sellers and H. Wang, *Joule*, 2023, **7**, 1887-1901.
77. Z. Lin, Felice, G. E. P. O'Connell, T. Wan, D. Zhang, L. Peng, D. Chu, X. Lu and Z. Han, *Chemical Engineering Journal*, 2024, **481**, 148736.
78. S. Schneider and M. Stöckl, *ACS Sustainable Chemistry & Engineering*, 2024, **12**, 5160-5168.
79. Y. Yuan, L. Chen, Z. Wan, K. Shi, X. Teng, H. Xu, P. Wu and J. Shi, *Science Advances*, **10**, eado1755.
80. S. Wu, H. Zhang, X. Huang and Z. Wei, *Chemical Communications*, 2022, **58**, 8942-8945.
81. K. Dong, Y. Wang, L. Zhang, X. Fan, Z. Li, D. Zhao, L. Yue, S. Sun, Y. Luo, Q. Liu, A. A. Alshehri, Q. Li, D. Ma and X. Sun, *Green Chemistry*, 2022, **24**, 8264-8269.
82. H. Xu, S. Zhang, X. Zhang, M. Xu, M. Han, L. R. Zheng, Y. Zhang, G. Wang, H. Zhang and H. Zhao, *Angewandte Chemie International Edition*, 2023, **62**, e202314414.
83. S. Zhang, M. Jin, H. Xu, X. Zhang, T. Shi, Y. Ye, Y. Lin, L. Zheng, G. Wang, Y. Zhang, H. Yin, H. Zhang and H. Zhao, *Energy & Environmental Science*, 2024, **17**, 1950-1960.
84. L.-Y. Dong, J.-S. Wang, T.-Y. Li, T. Wu, X. Hu, Y.-T. Wu, M.-Y. Zhu, G.-P. Hao and A.-H. Lu, *Angewandte Chemie International Edition*, 2024, **63**, e202317660.
85. Y. Song, X. Yang, H. Liu, S. Liang, Y. Cai, W. Yang, K. Zhu, L. Yu, X. Cui and D. Deng, *Journal of the American Chemical Society*, 2024, **146**, 5834-5842.
86. J. Qi, Y. Du, Q. Yang, N. Jiang, J. Li, Y. Ma, Y. Ma, X. Zhao and J. Qiu, *Nature Communications*, 2023, **14**, 6263.
87. H. Sheng, A. N. Janes, R. D. Ross, H. Hofstetter, K. Lee, J. R. Schmidt and S. Jin, *Nature Catalysis*, 2022, **5**, 716-725.
88. M. Wang, J. Cheng, W. Xu, D. Zhu, W. Zhang, Y. Wen, W. Guan, J. Jia and Z. Lu, *Nature Nanotechnology*, 2024, DOI: 10.1038/s41565-024-01815-x.
89. S. Chen, S. Liang, R. Huang, M. Zhang, Y. Song, Y. Zhang, S. Tao, L. Yu and D. Deng, *Nature Synthesis*, 2024, **3**, 76-84.