Supplementary Information

Economic evaluation and catalyst design for a hybrid water electrolysis system

Duzheng He[a], Yanping Zhao[a], Shen Wang[a], Kang Wang[a], Jiayi Wang[a], Weijie Li[b], Miao Fan[a], Yi Wei[a], Vasily Bautin[c], Chao Han*[a]

A. Supplementary notes：

Techno-economic screening considerations

From a cost perspective, the primary factor affecting catalyst price is the material used. Noble-metal-based catalysts are significantly more expensive than non-noble metal and metal-free catalysts. For simpler small molecules like methanol, ethanol, and glycerol, oxidation reactions proceed more easily, making non-noble metal catalysts the preferred choice due to their cost advantage. In contrast, the oxidation of more complex molecules such as benzyl alcohol, HMF, and glucose presents greater challenges for non-noble metal catalysts, which currently do not perform as well as noble metal catalysts. From this perspective, In general, noble-metal catalysts often deliver higher intrinsic activity for challenging substrates, whereas non-noble catalysts offer cost advantages but may require additional design to achieve comparable activity and selectivity. Consequently, different catalysts exhibit varying catalytic activities, which result in differences in energy efficiency in electrolytic systems, as shown in Table 1. Table 1 summarizes representative two-electrode HWE benchmarks for transformation reactions, while the complete dataset is provided in Table S1. Several trends emerge: (i) noble-metal catalysts often achieve lower cell voltages for challenging substrates (e.g., HMF/benzyl alcohol) but may face cost constraints; (ii) non-noble catalysts (especially Ni/Co-based materials) are widely used for alcohol oxidation with high Faradaic efficiencies, yet the realized energy saving depends strongly on current density and mass transport; (iii) for value-added products, reporting product titer and separation compatibility is essential, because downstream processing may dominate the net techno-economic outcome. Specifically, Energy saving efficiency[%] is calculated as $(V_{OWS}-V_{HWE})/V_{OWS}\times100\%$, where V_{OWS} and V_{HWE} are the cell voltages measured at the same current density for OWS and HWE, respectively. Generally, noble metal catalysts are more active than non-noble metal catalysts, thereby enhancing energy efficiency and reducing energy input. Currently, the oxidation of methanol, ethanol, and benzyl alcohol synergistically with water splitting can save 5%–20% energy input when using non-noble metal catalysts compared to the OWS system, while noble metal catalysts can achieve up to 70% energy savings. Due to its higher theoretical reaction potential and complex reaction pathways, HMF oxidation typically achieves only about 20% energy savings with most catalysts; however, recent advances with Cu-based catalysts have demonstrated significantly higher efficiencies. In theory, the reactions mentioned can achieve higher energy savings than OER, pending the future development of more efficient catalysts.

This review aims to compare alternative anodic oxidation reactions (AORs) from a techno-economic perspective; however, we emphasize that a full techno-economic analysis (TEA) is beyond the scope of a literature review because key outcomes depend on site-specific assumptions (electricity price, plant scale, electrolyzer CAPEX and lifetime, substrate supply chain, separation train, and product specifications). Instead, we provide a screening-level framework that connects electrochemical metrics to the main cost drivers and clarifies when HWE can be economically meaningful.

For an electrolyzer operated at a cell voltage E_{cell} with hydrogen Faradaic efficiency η_{F,H_2}, the specific electricity consumption can be approximated as

$$SEC_{elec}\approx26.8\times E_{cell}/\eta F,H2\ (\text{kWh kg}^{-1}\ H_2)$$

Therefore, the electricity saving from replacing OER by an AOR scales with ΔE_{cell}, but its economic impact must be evaluated together with additional material and separation costs.

AOR-assisted electrolysis is not “free” on the anode side. For an anodic reaction transferring nen_ene electrons per substrate molecule, the theoretical substrate requirement per mole of H_2 (2 e^-) is $2/n_{e,}$ before accounting for selectivity losses. This simple electron balance highlights a key trade-off: even when E_{cell} is reduced, the cost of the organic substrate can dominate unless (i) the substrate is a low-cost waste stream or carries a treatment credit, or (ii) the anodic product value is high enough that H_2 becomes a co-product rather than the primary economic target. Consequently, conversion-type HWE is often better interpreted as electrochemical upgrading with hydrogen co-production, whereas degradation-type HWE can be evaluated more directly as a hydrogen-centric process because it simultaneously delivers pollutant removal.

For conversion-type HWE generating value-added chemicals, the overall economics is frequently governed by downstream separation and electrolyte management rather than electrode performance alone. Product speciation in alkaline electrolytes (acid vs. salt), product titer, side-product formation, and electrolyte recyclability collectively determine separation complexity and cost. Therefore, meaningful economic comparisons should include separation-relevant metrics (product concentration/titer, isolation yield and purity, and electrolyte recyclability), in addition to Faradaic efficiency and cell voltage.To connect these factors, the levelized net hydrogen cost can be expressed conceptually as：

$$LCOH_{net}=\frac{CAPEX_{ann}+OPEX+C_{elec}+C_{substrate}+C_{sep}-R_{product}-credits}{mH_2}$$

where C_{elec} reflects electricity consumption, $C_{substrate}$ scales with $2/n_e$ and selectivity, C_{sep} captures separation/purification and recycling, and $R_{product}$ represents co-product revenue (if applicable). This framework clarifies that voltage reduction alone is insufficient to claim economic superiority, and it motivates co-design across electrocatalysis–electrolyzer–separation when screening promising HWE chemistries.

Generally, HMF is selectively converted to FDCA using noble metal-based catalysts (such as Au, Pt, Ru, and Pd) under high temperature (30-130 °C) and high-pressure oxygen (0.3-2.0 MPa) conditions. In contrast, HMF co-electrolysis operates under milder conditions, promotes the hydrogen economy, and reduces the energy input of electrolysis.[39] Moreover, the cost and source of raw materials for oxidation substrates are important considerations. Some raw materials used in oxidation reactions are valuable resources that can serve as raw materials for other chemical reactions. For example, commercial methanol produced by CO hydrogenation has conflicts in the hydrogen economy when used for methanol-assisted water electrolysis; ethanol and benzyl alcohol, as commonly used chemicals, have intrinsic high usage value.[40] From this perspective, biomass derivatives are more economical, and most biomass compounds and their derivatives contain active aldehyde groups, making the study of these aldehyde substances (such as HMF and glucose) more economically advantageous.

Based on the above screening framework, benzyl alcohol/HMF oxidation is attractive mainly as electrochemical upgrading with hydrogen co-production, whereas degradation-type HWE is more naturally positioned for hydrogen-centric deployment when waste-treatment credits apply.Despite significant progress in current research, further exploration is still needed to develop non-noble metal catalysts with high catalytic activity and selectivity for target products. Additionally, the presence of high-value oxidation products at the anode necessitates further consideration of their separation and purification in electrolyzer design. Therefore, the next sections will (i) summarize the latest research progress on catalysts and electrolyzer configurations for benzyl alcohol and HMF co-electrolysis and (ii) extend the same economic framework to hydrogen-carrier reactions (e.g., ammonia/methane), which are relevant to the overall cost of delivered H_2 through their impacts on energy input, catalyst cost, infrastructure readiness, and downstream separation/handling requirements.Based on the above discussion, the co-electrolysis of benzyl alcohol and HMF with water presents considerable research value and potential. Despite significant progress, translating these promising laboratory metrics into deployable HWE systems requires a system-level view beyond catalyst activity, including product separation and electrolyte recycling, durability under industrially relevant current densities and realistic feeds, operation under intermittent renewable electricity, and integration with existing infrastructure. Therefore, before summarizing recent catalyst advances for representative reactions, we first highlight these practical scale-up considerations and their techno-economic implications.

B. Supplementary tables：

Table S1. Summary of hybrid water electrolysis systems for transformation reactions.

Oxidation species	Electrocatalyst	Electrolyte	Anodic product	FE (H_2/anodic product) [%]	Voltage (V)/current density (mA cm^{-2})		Energy saving efficiency [%]	Refs.
					HWE	OWS		
Methanol	NiIr-MOF/NF	1.0 M KOH + 4 M methanol	formic acid	≈100 % / ≈100 %	E_{10} = 1.39	E_{10} = 1.56	10.92%	[41]
	CC@$NiCo_2S_4$	1.0 M KOH + 1.0 M methanol	formic acid	≈100% / ≈100%	E_{100} = 1.81	E_{100} = 2.29	18.23%	[42]
	$NiFe_2O_4$/NF	1.0 M KOH + seawater + 0.5 M methanol	formic acid	>96% / >95%	E_{100} = 1.74	E_{100} = 1.89	7.97%	[43]
	Fe_2O_3/NiO-NF	1.0 M KOH + 1.0 M methanol	formic acid	≈100% / 98%	E_{10} = 1.381	E_{10} = 1.516	8.79%	[44]
	NiFeLDH@NiMo/NF	1.0 M KOH + 0.5 M methanol	formic acid	≈100 % / 97 %	E_{100} = 1.54	E_{100} = 1.69	8.87%	[45]
	Os-NixP/N-C/NF	1.0 M KOH + 1.0 M methanol	formate	≈100 % / 92 %	E_{10} = 1.43	E_{10} = 1.52	5.92%	[46]
	NiCoMo	1.0 M KOH + 1.0 M methanol	formate	98 % / 85%	E_{50} = 1.46	E_{50} = 1.668	12.47%	[47]
	$Ni(OH)_2$/NF	1.0 M KOH + 0.5 M methanol	formate	92%/100%	E_{10} = 1.52	E_{10} = 1.70	10.59%	[48]
	CoxP@NiCo-LDH/NF	1.0 M KOH + 0.5 M	formate	≈100% / ≈100%	E_{10} = 1.43	E_{10} = 1.672	14.47%	[49]

		methanol						
	FeRu-MOF/NF	1.0 M KOH + 4.0 M methanol	formate	>90% / >90%	E_{10} = 1.40	E_{10} = 1.53	8.49%	[50]
	Pt-Co_3O_4/CP	1.0 M KOH + 2.0 M methanol	formate	≈100% / >66%	E_{10} = 0.555	E_{10} = 1.577	64.80%	[31]
Ethanol	Co-S-P/CC	1.0 M KOH + 1.0 M ethanol	acetic acid	— /67.2%	E_{10} = 1.63	E_{10} = 1.77	7.91%	[51]
	$CuCo_2S_4$/CC	1.0 M KOH + 1.0 M ethanol	acetic acid	——	E_{10} = 1.59	E_{10} = 1.74	8.62%	[52]
	Ni-Fe-P/NF	1.0 M KOH + 1.0 M ethanol	acetic acid	——	E_{10} = 1.53	E_{10} = 1.66	7.83%	[53]
	PdSP metallene	1.0 M KOH + 1.0 M ethanol	acetic acid	98.21%/ —	E_{10} = 0.88	E_{10} = 1.41	37.59%	[54]
	PtCu NF/C	1.0 M KOH + 0.5 M ethanol	acetic acid	92 % / 98.2%	E_{10} = 0.58	E_{10} = 1.88	69.14%	[55]
	SA In-Pt NWs/C	1.0 M KOH + 0.5 M ethanol	acetic acid	≈100 % / 93%	E_{10} = 0.62	E_{10} = 2.07	70.04%	[32]
Glycerol	CoP-Cu_3P/CC	1.0 M KOH + 0.1 M glycerol	formic acid	— /80%	E_{10} = 1.21	E_{10} = 1.42	14.78%	[56]
	NiVRu-LDHs NAs/NF	1.0 M KOH +0.1 M glycerol	formic acid	98% /97 %	E_{100} = 1.62	E_{100} = 1.99	18.69%	[57]
	CoNiCuMnMo-NPs/CC(+)||RhIr/Ti(−).	1.0 M KOH +0.1 M glycerol	formic acid	99%/92%	E_{10} = 1.34	E_{10} = 1.63	17.79%	[58]

	MnO_2/CP(+)||Pt/C/CP(−)	5m M H_2SO_4 + 0.2 M glycerol	formic acid	≈100% / ≈100%	E_{10} = 1.38	E_{10} = 1.78	22.47%	[59]
Benzyl alcohol	hp-Ni	1.0 M KOH + 10m M benzyl alcohol	benzoic acid	≈100%/97%	E_{10} = 1.50	E_{10} = 1.69	11.24%	[60]
	Ni@NiO_x	1.0 MKOH+0.1 M benzyl alcohol	benzoic acid	≈100%/96.5%	E_{10} = 1.438	E_{10} = 1.678	14.30 %	[61]
	Ni_2P/NF	1.0 M KOH + 10m M benzyl alcohol	benzoic acid	95.3%/99.3%	E_{10} = 1.45	E_{10} = 1.61	9.94 %	[33]
	Mo-Ni alloy	1.0 M KOH + 10m M benzyl alcohol	benzoic acid	≈100%/96.5%	E_{20} = 1.40	E_{20} = 1.61	13.04 %	[62]
	$NiCo_2O_4$/NF	1.0 M KOH + 50m M benzyl alcohol	benzoic acid	——	E_{10} = 1.51	E_{10} = 1.82	17.03%	[63]
	$ZnCo_2O_4$@$Ni(OH)_2$/NF	1.0 M KOH + 0.1 M benzyl alcohol	benzoate	— /96%	E_{10} = 1.456	E_{10} = 1.651	11.81%	[64]
HMF	MoO_2-FeP@C	1.0 M KOH + 10m M HMF	FDCA	≈100%/97.8%	E_{10} = 1.486	E_{10} = 1.592	6.66 %	[65]
	NF@Mo-$Ni_{0.85}$Se	1.0 M KOH + 10m M HMF	FDCA	≈100%/95%	E_{50} = 1.50	E_{50} = 1.68	10.71%	[66]
	Ni_3S_2/NF	1.0 M KOH + 10m M HMF	FDCA	≈100%/98%	E_{100} = 1.64	E_{100} = 1.84	10.87%	[67]
	Ni_2PNPA/NF	1.0 M KOH + 10m M HMF	FDCA	≈100%/98%	E_{50} = 1.58	E_{50} = 1.80	12.22%	[38]
	$Mn_{0.2}$NiS/GF	1.0 M KOH + 100m	FDCA	97.6%/94.2%	E_{100} = 1.35	E_{100} = 1.64	17.68%	[68]

		M HMF						
	Rh-SA/NiFe NMLDH	1.0 M KOH + 50m M HMF	FDCA	— /98.5%	E_{100} = 1.48	E_{100} = 1.74	14.94%	[69]
	Co$_{0.4}$NiS@NF	1.0 M KOH + 50m M HMF	FDCA	≈100%/99%	E_{100} = 1.29	E_{100} = 1.62	20.37%	[37]
Glucose	Fe$_{0.1}$-CoSe$_2$/CC	1.0 M KOH + 0.5 M glucose||0.5 mH2SO4	gluconate	86.7%/99%	E_{10} = 0.72	E_{10} = 1.34	46.27%	[70]
	Fe$_3$O$_4$/Au/CoFe-LDH	1.0 M KOH + 0.5 M Glucose(+)||0.5 M H2SO4(−)	Gluconate	≈100%/≈100%	E_{10} = 0.48	E_{10} = 1.60	70%	[71]
	Ru@Ni-B	1.0 M KOH + 0.1 M glucose	gluconate	——	E_{10} = 1.24	E_{10} = 1.42	12.67%	[72]
	Cu(OH)$_2$	1.0 M KOH + 0.1 M glucose	gluconic acid	≈100%/98.7%	E_{100} = 0.92	E_{100} = 1.90	51.58%	[73]
	RuV-Co(OH)$_2$/NF	1.0 M KOH + 0.1 M glucose	gluconic acid	97.78%/ —	E_{10} = 1.42	E_{10} = 1.66	14.46%	[74]
	Ta NiFe LDH/NF	1.0 M KOH + 0.1 M glucose	gluconic acid	— /64.3%	E_{10} = 1.62	E_{10} = 1.87	13.37%	[75]

Table S2. Summary of hybrid water electrolysis systems for degradation reactions.

Oxidation species	Electrocatalyst	Electrolyte	Anodic product	FE (H_2) [%]	Voltage (V)/current density (mA cm^{-2})		Energy saving efficiency [%]	Refs.
					HWE	OWS		
N_2H_4	Mo-Ni_3N/Ni/NF	1.0 M KOH + 0.1 M N_2H_4	N_2	≈100%	E_{100} = 0.265	E_{100} = 2.10	87.38	[86]
	RP-CPM	1.0 M KOH + 0.3 M N_2H_4	N_2	99.5%	E_{100} = 0.227	E_{100} = 2.846	92.02	[87]
	Ni-C HNSA	1.0 M KOH + 0.1M N_2H_4	N_2	≈100%	E_{200} = 0.40	E_{200} = 1.90	78.95	[88]
	NiCo-$MoNi_4$HMNAs/NF	1.0 M KOH + 0.1 M N_2H_4	N_2	≈100%	E_{100} = 0.315	E_{100} = 2.28	86.18	[89]
	$(Ni_{0.6}Co_{0.4})_2P$	1.0 M KOH + 0.1 MN_2H_4	N_2	> 99%	E_{10} = 0.228	E_{10} = 1.784	87.22	[90]
	Pt-Rhene	1.0 M KOH + 0.1 M N_2H_4	N_2	≈100%	E_{100} = 0.28	E_{100} = 1.98	85.86	[91]
	Cu1Pd_3/C	1.0 M KOH + 0.5 M N_2H_4	N_2	—	E_{10} = 0.505	E_{10} = 1.960	74.23	[92]
	Au_1Pt_8	1.0 M KOH + 0.5 M N_2H_4	N_2	—	E_{10} = 0.172	E_{10} =1.773	90.30	[93]
	Ni/β-$Ni(OH)_2$	1.0 M KOH + 0.3 M N_2H_4	N_2	92%	E_{10} = 0.16	E_{10} = 1.32	87.88	[94]
	FeCo-Ni_2P@MIL-FeCoNi	1.0 M KOH + 0.5 M N_2H_4	N_2	≈100%	E_{100} = 0.242	E_{100} = 1.65	85.33	[95]

Co/BNC	1.0 M KOH + 0.1 M N_2H_4	N_2	94%	E_{100} = 0.617	E_{100} = 1.96	68.52	[96]
Rh_2P uNSs	0.5 M H_2SO_4 + 50 m M N_2H_4	N_2	—	E_{10} = 0.377	E_{10} = 1.75	78.46	[97]
Ce-Ni_3N/NF	1.0 M KOH + 0.5 M N_2H_4	N_2	—	E_{10} = 0.156	E_{10} = 1.595	90.22	[98]
Ru-Cu_2O/CF	1.0 M KOH + 0.5 M N_2H_4	N_2	—	E_{100} = 0.076	E_{100} = 1.75	95.66	[99]
PW-Co_3N	1.0 M KOH + 0.1 M N_2H_4	N_2	96%	E_{100} = 0.171	E_{100} = 1.88	90.90	[100]
N-mRu/NF	1.0 M KOH + 0.5 M N_2H_4	N_2	≈100%	E_{100} = 0.184	E_{100} = 1.655	88.89	[101]
MoNi@NF	1.0 M KOH + 0.5 M N_2H_4	N_2	≈100%	E_{100} = 0.21	E_{100} = 1.72	87.79	[102]
CC@WS_2/Ru-450	1.0 M KOH + 0.5 M N_2H_4	N_2	≈100%	E_{10} = 0.0154	E_{10} = 1.72	99.10	[103]
Ru-FeP_4/IF	1.0 M KOH + 0.5 M N_2H_4	N_2	≈100%	E_{1000} = 0.90	E_{1000} = 2.10	57.14	[104]
Fe/F-Ni_2P@NC	1.0 M KOH + 0.5 M N_2H_4	N_2	≈100%	E_{100} = 0.336	E_{100} = 1.65	79.63	[105]
a-RhPb NFs	1.0 M KOH + 0.1 M N_2H_4	N_2	≈100%	E_{100} = 0.321	E_{100} = 1.764	81.80	[106]
Cu_xSe/CF	1.0 M KOH + 0.2 M N_2H_4	N_2	—	E_{25} = 0.49	E_{25} = 1.77	72.31	[107]

	$RhRu_{0.5}$	1.0 M KOH + 1.0 M N_2H_4	N_2	94.1%	E_{10} = 0.054	E_{10} = 1.644	96.71	[80]
Urea	NiCo-ZLDH/NF	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	—	E_{100} = 1.368	E_{100} = 1.581	13.47	[108]
	O-vac-V-$Ni(OH)_2$	1.0 M KOH + 0.33 M urea	$CO_2 + N_2$	—	E_{10} = 1.50	E_{10} = 1.67	10.18	[78]
	CC−Ni/NiO@NCS	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	—	E_{10} = 1.475	E_{10} = 1.739	15.18	[109]
	Cu-Ni_3S_2@NiFe LDH-200	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	—	E_{100} = 1.585	E_{100} = 1.789	11.40	[110]
	S-Co_2P@Ni_2P	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	98.8%	E_{10} = 1.43	E_{10} = 1.52	5.92	[111]
	Co_xMo_yCH	1.0 M KOH + 0.33 M urea	$CO_2 + N_2$	—	E_{10} = 1.40	E_{10} = 1.51	7.28	[112]
	Ce-Ni_3N@CC	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	—	E_{10} = 1.31	E_{10} = 1.521	13.87	[113]
	P-$CoNi_2S_4$	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	—	E_{10} = 1.402	E_{10} = 1.544	9.19	[114]
	N-Co_9S_8/Ni_3S_2/NF	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	98%	E_{10} = 1.40	E_{10} = 1.55	9.67	[115]
	Fe-$Co_{0.85}Se$/FeCo LDH	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	≈100%	E_{100} = 1.52	E_{100} = 1.63	6.75	[116]
	O-NiMoP/NF	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	—	E_{10} = 1.36	E_{10} = 1.58	13.92	[117]

	PBA@MOF-Ni/Se	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	—	E_{10} = 1.491	E_{10} = 1.735	14.06	[118]
	Mo-NiCoP@NiCoP/ $Ni_xCo_yH_2PO_2$	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	—	E_{10} = 1.348	E_{10} = 1.522	11.43	[119]
	NiF_3/Ni_2P@CC-2	1.0 M KOH + 0.33 M urea	$CO_2 + N_2$	—	E_{10} = 1.54	E_{10} = 1.58	2.53	[120]
	P-Ni@$CoMoO_4$/CF	1.0 M KOH + 0.33 M urea	$CO_2 + N_2$	—	E_{100} = 1.50	E_{100} = 1.67	10.18	[121]
	Sn(2)-CoS_2	1.0 M KOH + 0.5 M urea	$CO_2 + N_2$	—	E_{10} = 1.45	E_{10} = 1.675	16.41	[122]
	Pt-$Ni(OH)_2$@Ni-CNFs	1.0 M KOH + 0.33 M urea	$CO_2 + N_2$	—	E_{10} = 1.400	E_{10} = 1.635	14.37	[79]
Sulfide	Ni-Co-C/NF	1.0 M NaOH + 1.0 M Na_2S	S_8	—	E_{100} = 0.531	E_{100} = 1.822	70.85	[20]
	Co-Ni_3S_2	1.0 M NaOH + 1.0 M Na_2S	S_8	—	E_{50} = 0.80	E_{50} = 1.99	59.80	[123]
	CoS_2@C/MXene	1.0 M NaOH + 1.0 M Na_2S	S_8	—	E_{200} = 0.68	E_{200} = 1.85	63.24	[124]
	Co_3S_4Nanowires	1.0 M NaOH + 1.0 M Na_2S	S_8	—	E_{100} = 0.262	E_{100} = 1.521	82.77	[125]
	NiSe/NF	1.0 M NaOH + 1.0 M Na_2S	S_8	—	E_{100} = 0.49	E_{100} = 1.78	72.47	[126]
	NiS_2	1.0 M NaOH + 1.0 M Na_2S	S_8	—	E_{20} = 0.65	E_{20} = 1.68	61.30	[127]

WS_2 nanosheets	1.0 M NaOH + 1.0 M Na_2S	S_8	99.22%	E_{10} = 1.17	E_{10} = 2.16	45.83	[128]
NiFe-LDH/Cu-IF	1.0 M KOH + 0.5 M NaCl + 1.0 M Na_2S	S_8	—	E_{50} = 0.619	E_{50} =1.905	67.50	[129]
HEDP-Rh metallene	1.0 M KOH + 4.0 M Na_2S	S_8	—	E_{100} = 1.082	E_{100} = 2.407	55.08	[130]