Supplementary Information (SI) for Environmental Science: Nano.

Supplementary Materials for

Polyoxometalates in Environmental Remediation and Energy Storage

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1. POM-based catalysts in removal of refractory sulfur compounds from fossil fuels

Table S1 The summary of literature known POM-based catalysts and their efficiency in removal of refractory sulfur compounds from fossil fuels.

Formula	POM archetype	Conditions	Efficiency	Number of cycles	Ref.
$[H_3PW^{VI}_{12}O_{40}\cdot 20H_2O]$; $[Na_3PW^{VI}_{12}O_{40}\cdot 14H_2O]$; $[H_3PMo^{VI}_{12}O_{40}\cdot 15H_2O]$; $[Na_3PMo^{VI}_{12}O_{40}\cdot 20H_2O]$; $[H_4SiW^{VI}_{12}O_{40}\cdot 25H_2O]$; $[H_4SiMo^{VI}_{12}O_{40}\cdot xH_2O]$, x = not specified by authors (nsp)	Keggin	T = 50-70°C; t = 90 min; solvent – toluene; 30 % H_2O_2 as oxidant; n(catalyst) = 0.063 mmol; n(DBT) = 5.43 mmol; DBT = dibenzothiophene	DBT removal efficiency of 100 % within 90 min (k = 0.064 min^{-1})	nsp	[1]
POM/PEG/SSA; POM = $Na_3H_6Cr^{III}Mo^{VI}_6O_{24}$, PEG = polyethylene glycol, SSA = 5-sulfosalicylic acid	Anderson-Evans	T = 60 °C; t = 2 h; p(O_2) = 1 atm, 60 mL/min O_2 flow rate; V_{oil}/V_{DES} = 5; O_2 as oxidant; model diesel ([S] = 500 ppm in decalin); V(model diesel) = 20 mL; m(POM) = 0.02 g; V(DES)= 4 mL; DES = deep eutectic solvent; DBT = dibenzothiophene	DBT removal efficiency of 100 % within 120 min (k = 0.028 min^{-1})	5	[2]
$H_8PV^V_5Mo^{VI}_7O_{40}$ (HPA-5)	Keggin	T = 140 °C; t = 6 h; p = 20 bar; n(HPA-5) = 2.50 mmol; V_{H2O}/V_{oil} = 10; O_2 – oxidant; model oil (3.35 g of BT in 100 mL isooctane; [S] = 11483 ppm); BT = benzothiophene	BT removal efficiency of 99 % within 6 h	at least 3	[3]
CNTs@PDDA@$Mo_{16}V_2$; $Mo_{16}V_2$ = $H_8P_2Mo^{VI}_{16}V^V_2O_{62}\cdot mH_2O$, m = not specified by authors (nsp), CNTs = carbon nanotubes, PDDA = poly(diallyldimethylammonium chloride)	Wells-Dawson	T = 70 °C; t= 3 h; O_2 flow 1.5 L/min; O_2 as oxidant; [catalyst] = 1.0 g/L; model fuel (2.87 g DBT in 250 mL n-octane; [S] = 2000 ppm); DBT = dibenzothiophene	DBT removal efficiency of 99.4 % within 3 h	8	[4]
$[C_4VIM]PMoV_2$; $PMoV_2 = H_5PMo^{VI}_{10}V^V_2O_{40}$, $[C_4VIM]$ = 1-butyl-3-vinylimidazolium cation	Keggin	T = 120 °C; t = 5 h; V(air) = 100 mL/min; m(catalyst) = 0.05 g; model oil ([S] = 200 ppm; DBT, 4-MDBT or 4,6-DMDBT in dodecane); V(model oil) = 20 mL; DBT = dibenzothiophene; 4-MDBT = 4-methyldibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	desulfurization efficiency of 98.9 % within 5 h	7	[5]
Co-Pc/PMoV; PMoV = $[(NH_4)_5H_6PV^V_8Mo^{VI}_4O_{40}\cdot 27H_2O]$, Co-Pc = cobalt phthalocyanine	Keggin	T = 100 °C; t = 5 h; p = 1 atm; m(catalyst) = 12 mg; O_2 – oxidant; model oil ([DBT] = 500 ppm in 6 mL decalin); DBT = dibenzothiophene	DBT removal efficiency of 97.6 % within 5 h (k = 24.21 h^{-1}) and for inorganic sulfur S^{2-} (k = 29.12 h^{-1})	at least 9	[6]
$Tb(PW_{11})_2$@MIL-101; $Tb(PW_{11})_2$ = $[Tb(PW^{VI}_{11}O_{39})_2]^{11-}$, MIL-101 = metal-organic framework	lacunary Keggin	T = 50 °C; t = 2-5 h; solvent – MeCN; DBT = dibenzothiophene	DBT removal efficiency of 95 % after 2 h, 100 % efficiency after 5 h	3	[7]
0,1-$C_{16}SiW$–TiO_2; SiW = $[Si^{IV}W^{VI}_{12}O_{40}]^{4-}$	Keggin	T = 50 °C; t = 60 min; m(catalyst) = 10 mg; n(H_2O_2) = 2 mol; n(O/S) = 2; model oil (DBT, 3-MBT, 4-MDBT in n-octane, [S] = 500 ppm); V(model oil) = 5 mL; DBT = dibenzothiophene; 3-MBT = 3-methylbenzothiophene; 4-MDBT = 4-methyldibenzothiophene	DBT removal efficiency of 95.3 % within 60 min	8	[8]
PIL/$H_2W^{VI}_{12}O_{42}^{10-}$; PIL = Polymeric Ionic Liquid	paratungstate	T = 30 °C; t = 90 min; m(catalyst) = 25 mg; m(model oil) = 10 g; model oil (BT and DBT in n-dodecane, $[S]_0$ = 1000 ppm); real diesel ([S] = 559.7 ppm); H_2O_2 as oxidant; n(H_2O_2/S) = 4; DBT = dibenzothiophene; BT = benzothiophene	DBT removal efficiency of 92.1 % and BT removal efficiency of 58.3 % within 90 min	8	[9]
		T = 60 °C; t = 3-5 h; solvent – hexane; V(hexane) = 5 mL; extraction solvent – DMF or MeCN; V(DMF or MeCN) = 5 mL or 50 mL;	DBT removal efficiency of 99 %, 4,6-DMDBT removal efficiency of 80 %		

		[AcOH]/[H_2O_2] = 1; [substrate] = 0.01 M; [catalyst] = 1.25 x 10^{-4} M; substrate/catalyst = 80-100; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	(k(BT) = 0.0103 min^{-1}; k(DBT) = 0.0171 min^{-1} and k(4,6-DMDBT) = 0.0152 min^{-1})		
$Na_3Fe^{III}(OH)_6Mo^{VI}_6O_{18}$/PEG2000/BSA; PEG2000 = Polyethylene Glycol 2000, BSA = Bovine Serum Albumin	Anderson-Evans	T = 60 °C; t = 60 min; p= 1 atm; 2000 PEG/2.5 BSA (n(PEG2000)/n(BSA) = 2.5); O_2 as oxidant; m(catalyst) =10 mg; m(DESs) = 4 g; model oil ($[S]_0$ = 500 ppm); V(model oil) = 20 mL; DESs= deep eutectic solvents; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	DBT and 4,6-DMDBT removal efficiency of 99 % in 180 min, BT 95 % in 240 min	5	[11]
$[Bmim]_3[PW^{VI}_{12}O_{40}]$; $[Bmim]^+$ = 1-butyl-3-methylimidazolium cation	Keggin	T = 80 °C; p =1 atm; H_2O_2 – oxidant; $[Bmim]BF_4$ – solvent; m(catalyst) = 0.5 g; V(solvent) = 5 ml; m(petcoke) = 0,5 g; 5 mL of 30 % H_2O_2; t = 5 h + drying for 24 h at 100 °C; petcoke pretreated by tetrabutylammonium chloride	sulfur removal efficiency of 36.10 % within 5 h	nsp	[12]
$K_x[PMo^{VI}_{12}O_{40}]$; x = 1, 2, 3, 4	Keggin	T = 60 °C; t = 60 min; V(model oil) = 15 mL; V(CH_3OH) = 15 mL; m(catalyst) = 0.2 g; H_2O_2 – oxidant; n(H_2O_2)/n(DBT) = 4; V(model oil)/V(CH_3OH) =1.5:1; DBT = dibenzothiophene	DBT removal efficiency of 99 % within 60 min for x = 4 (k = 0.076 min^{-1})	5	[13]
$P[C_2V]Mo^{VI}V^V$/AC; $MoV = H_8P_2Mo^{VI}_{16}V^V_2O_{62}$; AC = activated carbon	Wells-Dawson	T = 70 °C; t = 180 min; O_2 – oxidant; model oil (DBT, 4-MDBT or 4,6-DMDBT in n-octane; [S] = 2000 ppm); V(model oil) = 50 mL; O_2 flow rate 1.5 L/min; n(POM) = 15 µmol; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 4-MDBT = 4-methyldibenzothiophene	DBT removal efficiency of 99.2 % within 180 min	8	[14]
n-[Pmim]PMo/HAP; *n* = 10, 25; $PMo = H_3PMo^{VI}_{12}O_{40}$, *n*-$[Pmim]^+$ = 1-propyl-3-methylimidazolium cation, HAP = hydroxyapatite	Keggin	T = 40 °C; t = 60 min; n(O/S) = 6; m(catalyst) = 0.1 g; model oil (DBT in n-octane; [S] = 500 ppm); V(model oil) = 5 mL; V(IL) = 1 mL; H_2O_2 – oxidant; DBT = dibenzothiophene; IL = ionic liquid	DBT removal efficiency of 97.2 % in 60 min	6	[15]
POM–PAF-1; $POM = [Mo^{VI}_8O_{26}]^{4-}$, PAF-1 = Porous Aromatic Framework-1	octamolybdate	T = 30 °C; t = 30 min; H_2O_2 as oxidant; V(H_2O_2) = 50 µL; m(catalyst) = 40 mg; 75 µL of glacial acetic acid; V(MeCN) = 1.0 mL; n(H_2O_2)/n(DBT) = 6; model oil (TP, BT, DBT or 4,6-DMDBT in n-octane; [S] = 500 ppm); V(model oil) = 5 mL; TP = thiophene; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	DBT removal efficiency of 98.5 % within 30 min (k = 0.125 min^{-1})	5 (2 % activity loss)	[16]
PW/UiO-66(Zr); $PW = H_3PW^{VI}_{12}O_{40}$, UiO-66(Zr) = zirconium-based metal-organic framework	Keggin	T = rt; t = 25 min; m(catalyst) = 50 mg, m(model fuel) = 10 g; m(MeCN) = 10 g; O/S = 6; model fuel (BT, DBT or 4,6-DMDBT in n-octane; [S] =1000, 1000 or 500 ppmw); BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	DBT removal efficiency of 98.2 % within 25 min (TOF = 293 h^{-1})	at least 4	[17]
$PW_{11}Zn$@aptesPMOE; $PW_{11}Zn$ = $[PW^{VI}_{11}Zn^{II}(H_2O)O_{39}]^{5-}$, aptesPMOE = (3-aminopropyl)triethoxysilane (APTES) grafted onto poly(methyl oxazoline) (PMOE)	lacunary Keggin	T = 70 °C; H_2O_2 – oxidant; n(catalyst) = 3 µmol; MeCN – extraction solvent; in model oil: model oil/MeCN = 1:1; n(H_2O_2/S) = 4 (solvent free) and (with MeCN) = 8; t = 1 h in real diesel: in MeCN/diesel = 1:1, t = 120 min; n(H_2O_2/S) = 8	complete desulfurization after 4 h for a biphasic system, 1.5 h for solvent-free system	10	[18]
CNC@PIL@POM; $POM = [Co(OH)_6Mo^{VI}_6O_{18}]^{3-}$, CNC = cellulose nanocrystals, PIL = polymeric ionic liquid	Anderson-Evans	T = 100 °C; t = 3 h; O_2 from air as oxidant; m(catalyst) = 20 mg; model diesel (BT, DBT or 4,6-DMDBT in decahydronaphthalene; [S] = 500 ppm); V(diesel) = 20 mL; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	Complete desulfurization within 3 h (k = 1.277 h^{-1})	at least 5	[19]
		T = 60 °C; t = 120 min; m(catalyst) = 50 mg; model diesel (DBT in n-hexane; [S] = 500			

		ppmw); V(model diesel) = 12.5 mL; V(TBHP) = 0.9 mL; DBT = dibenzothiophene; TBHP = tert-butyl hydroperoxide; ppmw = parts per million by weight			
TBA-$PW_{11}NiO_{39}$@PANI; TBA-$PW_{11}NiO_{39}$ = ((n-$C_4H_9)_4N)_4H[PW^{VI}{}_{11}Ni^{II}O_{39}$], PANI = polyaniline	lacunary Keggin	T = 35 °C; t = 60 min; V(H_2O_2/HOAc) = 6 mL as oxidant v/v 2:1; m(catalyst) = 0.1 g; model oil (TH, BT and DBT in n-heptane; [S] = 500 ppm); V(model oil) = 50 mL; MeCN – extraction solvent; V(MeCN) = 10 mL; TH = tetrahydrothiophene; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	DBT removal efficiency of 97 %, BT and TH removal efficiency of 96 % within 60 min (k(DBT) = 0.936 min^{-1}, k(BT) = 0.9477 min^{-1}, k(TH) = 0.91 min^{-1})	5	[21]
$PMo_{11}Cd$@$MnFe_2O_4$; $PMo_{11}Cd = PMo^{VI}{}_{11}Cd^{II}O_{39}$	lacunary Keggin	T = 35 °C; t = 1 h; V(H_2O_2/HOAc) = 3 mL oxidant (v/v 2:1); m(catalyst) = 0.1 g; model fuel (Th, BT, DBT in n-heptane; [S] = 500 ppm); V(model fuel) = 50 mL; Th = thiophene; BT = benzothiophene; DBT = dibenzothiophene	DBT removal efficiency of 98 % and BT removal efficiency of 97 % within 1h (k(BT) = 0.091 min^{-1}, k(DBT) = 0.111 min^{-1})	5 (3 % of activity loss)	[22]
$(NR_4)_3[X^{III}Mo^{VI}{}_6O_{24}H_6]$; X = Cr, Fe, Co; R = H or alkyl	Anderson-Evans	T = 120 °C; t = 1 h; O_2 as oxidant; air flow rate 6 L/h; n(S)/n(catalyst) = 50:1; model fuel (DBT in decalin, [S] = 500 ppm); V(model fuel) = 30 mL; DBT = dibenzothiophene	Complete removal of DBT within 1 h (CoMo-POM)	2	[23]
$La^{III}W^{VI}{}_{10}O_{36}$@MIL-101(Cr); $LaW_{10}O_{36} = Na_7[H_2LaW_{10}O_{36}]$, MIL-101(Cr) = chromium (III)-based metal-organic framework	Weakley	T = 60 °C; t = 120 min; H_2O_2 – oxidant; n-octane/MeCN biphasic solvent system; m(catalyst) = 40 mg; n(O/S) = 6; V(model gasoline) = 5 mL; V(MeCN) = 5 mL; DBT = dibenzothiophene	99.1 % DBT conversion in 180 min	at least 7	[24]
PMo_{12}@UiO-67; $PMo_{12} = H_3PMo^{VI}{}_{12}O_{40}$, UiO-67 = zirconium-based metal-organic framework	Keggin	T = 50 °C; t = 30 min; H_2O_2 – oxidant; n(H_2O_2/S) = 3, m(POM@MOF) = 0.015 g; V(model fuel) = 0.5 mL; V(MeCN) = 0.5 mL; model fuel (Th, BT, DBT, 4-MDBT and 4,6-DMDBT in n-octane; [S] = 500 ppm); MOF = metal-organic framework; Th = thiophene; BT = benzothiophene; DBT = dibenzothiophene; 4-MDBT = 4-methlydibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	95.5 % DBT conversion in 30 min	6	[25]
$Fe_2W_{18}Fe_4$@$FeTiO_3$; $Fe_2W_{18}Fe_4$ = $Na_9K[(Fe^{III}W^{VI}{}_9O_{34})_2Fe^{III}{}_4(H_2O)_2]\cdot 32H_2O$	Sandwich-type	T = 35 °C; t = 60 min; H_2O_2/HOAc – oxidant (v:v 2/1, 3 mL); MeCN – extraction solvent; V(solvent) = 10 mL; m(catalyst) = 0.1 g; model fuel (Th, BT and DBT in n-heptane; [S] = 500 ppmw); V(model fuel) = 50 mL; Th = thiophene; BT = benzothiophene; DBT = dibenzothiophene; ppmw = parts per million by weight	DBT removal efficiency of 99 %, BT removal of 98 % and TH removal of 96 % within 60 min (k(Th) = 0.046 min^{-1}, k(BT) = 0.050min^{-1}, k(DBT) = 0.055 min^{-1})	5	[26]
ZIF-8@{Mo_{132}}; ZIF-8 = zeolitic imidazolate framework	Keplerate (nanoball)	T = 80 °C; t = 12 h; V(THBP) = 4 µL as oxidant; n(O/S) = 1; m(catalyst) = 150 mg; model fuel (500 mg DBT in 1 L of toluene); V(model fuel) = 15 mL; DBT = dibenzothiophene; TBHP = tert-butyl hydroperoxide	DBT removal efficiency of 92 % within 12 h (k = 0.0016 h^{-1})	5	[27]
$H_{11}P_2W^{VI}{}_{13}V^{V}{}_5O_{52}$/TMA-Si; TMA-Si = tetramethylammonium-functionalized silica	Wells-Dawson	T = 70 °C; t = 30 min; p = 1 atm; H_2O_2 – oxidant; [catalyst] = 7.5 g/L; V(solvent)/V(model oil) = 1:6; MeCN – extraction solvent; model oil ([S] = 500 ppmw in 2,2,4-trimethyl pentane and 20 v% toluene); ppmw = parts per million by weight	95 % efficiency for model oil and 83 % for real diesel in 30 min	at least 5	[28]
PW_{12}@TiO_2; $PW_{12} = H_3PW^{VI}{}_{12}O_{40}$	Keggin	T = 60 °C; t = 60 min; H_2O_2/HOAc – oxidant; V(MeCN) = 6 mL; model oil ([S] = 500 ppm); V(model oil) = 5 mL; n(O/S) = 6; m(catalyst) = 0.09 mol; DBT = dibenzothiophene	DBT removal efficiency of 99.9 % within 60 min	at least 7	[29]
(n-$C_4H_9)_4N]_7H_5[Si^{IV}{}_2W^{VI}{}_{18}Cd^{II}{}_4O_{68}$]	Sandwich	T = 60 °C; t = 2 h; m(catalyst) = 0.1 g; V(MeCN) = 10 mL; V(H_2O_2/HOAc, v/v 1:1) = 6 mL as oxidant; MeCN – extraction solvent; model fuel (thiophenic compounds in n-	DBT removal efficiency of 98 % within 2 h for model fuel	at least 5	[30]

		heptane; [S] = 500 ppmw); V(model fuel) = 50 mL; DBT = dibenzothiophene; ppmw = parts per million by weight			
{Mo_{132}}/GO; GO = graphene oxide	Keplerate (nanoball)	T = 60 °C; t = 150 min; H_2O_2 – oxidant; MeCN – extraction solvent; model oil (DBT in n-dodecane, [S] = 500 ppm); n(H_2O_2/DBT) = 6; [catalyst] = 10 g/L; DBT = dibenzothiophene	DBT removal efficiency of 99 % for {Mo_{132}}/GO and 96 % for {Mo_{132}} within 150 min ({Mo_{132}}: k = 0.0196 h^{-1}, {Mo_{132}}/GO: k = 0.0311 h^{-1})	10	[31]
$(NH_4)_5H_6PV^V_8Mo^{VI}_4O_{40}$	Keggin	T = 100 °C; t = 6 h; m(catalyst) = 20 mg; O_2 – oxidant; p = 1 atm; model oil (DBT in decalin; [S] = 500 ppm); V(model oil) = 6 mL; DBT = dibenzothiophene; Th = thiophene	100 % conversion of DBT and 97 % of Th within 6 h	10	[32]
PhPyBs-PW; PW = $H_3PW^{VI}_{12}O_{40}$, PhPyBs = ionic liquids containing 4-phenyl-pyridine (PhPy) and 1,4-butane sultone (Bs)	Keggin	T = rt or 70 °C; t = 10 min; m(catalyst) = 40 mg; H_2O_2 30 % aq, n = 1 mmol; H_2O_2/S = 1:1; 4 mL of H_2O or H_2O:EtOH (5 mL, v/v = 7:3); model fuel (DBT in 4 mL n-hexane; [S] = 100, 700 and 1000 ppm); DBT = dibenzothiophene	sulfur removal efficiency of 90 % within 10 min in model oil	5	[33]
$H_3PW^{VI}_6Mo^{VI}_6O_{40}$	Keggin	T = 60 °C; t = 90 min; solvent – MeCN; V(MeCN) = 60 mL; model fuel (sulfur compound in 60 mL octane; sulfur content of 0.050 mass %)	90.26 % thiophene removal efficiency within 90 min	at least 2	[34]
$[PyPS]_3Co^{III}(OH)_6Mo^{VI}_6O_{18}$/PEG2000/BSA; [PyPS] = pyridylphenylsulfonate, PEG2000 = polyethylene glycol 2000, BSA = bovine serum albumin	Anderson-Evans	T = 60 °C; p = 1 atm; O_2 as oxidant; m(DES) = 4 g; n(HBA):n(HBD) = 1:2; V(model oil) = 20 mL; m(POM) = 20 mg; O_2 flow 60 mL/min; t = 4 h for model oil; t = 8 h for commercial diesel; T = 80 °C for commercial diesel; HBA = hydrogen bond acceptor; HBD = hydrogen bond donor; DBT = dibenzothiophene	98 % DBT removal efficiency within 3 h	5	[35]
$[(NH_4)_5(CTA)_6PMo^{VI}_4V^V_8O_{40}]$; CTA = cetyltrimethylammonium	Keggin	T = 80-100 °C; t = 4-8 h; p = 1 atm; O_2 – oxidant; model oil ([DBT] = 500 ppm, V(decalin) = 6 mL); n(catalyst) = 0.05 mmol; DBT = dibenzothiophene	DBT removal efficiency of 100 % within 8 h at 100 °C	10	[36]
$[C_2(MIM)_2]PW^{VI}_{12}O_{40}$; $[C_2(MIM)_2]$ = 1-ethyl-3-methylimidazolium	Keggin	T = 50 °C; t = 60 min; n(catalyst)/n(S) = 0.025; n(H_2O_2)/n(S) = 6; H_2O_2 – oxidant; V(model oil) = 5 mL (DBT in n-octane); V(MeCN) = 0.5 mL; DBT = dibenzothiophene	DBT removal efficiency of 98.4 % within 60 min	at least 7	[37]
([*n*-$C_4N_9]_4N)_4H[PW^{VI}_{11}FeO_{39}]$/NiO	Keggin	T = 35 °C; t = 60 min; model oil ([S] = 500 ppm in n-heptane); V(model oil) = 50 mL; V(H_2O_2/AcOH) = 3 mL (v/v = 1:2); extraction solvent – MeCN; m(catalyst) = 0.1 g; DBT = dibenzothiophene	97 % of total sulfur (wt%) removed in real gasoline within 60 min (DBT rate constant k = 0.049 min^{-1})	at least 5	[38]
Al_2O_3-$P_2W^{VI}_{15}$-C_n; P_2W_{15} = $Na_{12}[\alpha$-$P_2W^{VI}_{15}O_{56}]\cdot 24H_2O$, C_n, where n = 8, 12 or 18	Wells-Dawson	T = 60 °C; t = 9 min; H_2O_2 – oxidant; model oil (DBT, BT and 4,6-DMDBT in n-octane, [S] = 1000 ppm); V(model oil) = 5 mL; m(catalyst) = 116.0 mg; V(H_2O_2) = 48.0 µL; real diesel sample ([S] = 425 ppm); n(H_2O_2)/n(S) = 3:1; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	100 % of sulfur removal within 9 min at 60 °C	at least 10	[39]
$PW^{VI}_{12}O_{40}$@$MnFe_2O_{40}$	Keggin	T = 35 °C; t = 60 min; model fuel (500 ppm of Th, BT and DBT in n-heptane); V(model fuel) = 50 mL; V(oxidant) = 3 mL; oxidant system: H_2O_2/acetic acid v/v = 2:1; p = 1 atm; m(catalyst) = 0.1 g; Th = thiophene; BT = benzothiophene; DBT = dibenzothiophene	DBT removal efficiency of 98 % in model oil and 96 % in real fuel within 60 min (rate constant for DBT, k = 0.053 min^{-1})	5	[40]
$K_{10}[\alpha$-$P_2W^{VI}_{17}O_{61}]\cdot 20H_2O$/3D GO; 3D GO = three-dimensional graphene oxide	Wells-Dawson	for model oil: T = 60 °C; t = 30-120 min; model oil (sulfur-containing compounds: DBT, BT and 4,6-DMDBT in n-octane, [S] = 500 ppm); V(model oil) = 20 mL; m(catalyst) = 0.08 g; V(H_2O_2, 30 % aq) = 100 µL; H_2O_2 – oxidant; V(MeCN) = 20 mL; for THT: m(catalyst) = 0.02 g; V(MeCN) = 5 mL; V(H_2O_2, 30% aq) = 100 µL; H_2O_2 – oxidant; T = 25 °C;	complete removal of DBT and THT within 120 min and 30 min, respectively	5	[41]

		BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; THT = tetrahydrothiophene			
P[Vim]POM/GO; P[Vim] = 1-ethyl-3-methylimidazolium cation, POM = $H_8P_2Mo^{VI}_{16}V^{V}_{2}O_{62}{\cdot}14H_2O$, GO = graphene oxide	Wells-Dawson	T = 60 °C; t = 60-120 min; m(catalyst) = 0.13 g; $n(H_2O_2)/n(S)$ = 9; model fuel ([S] = 2000 ppm in octane); V(model fuel) = 10 mL; extraction solvent – DMF; V(DMF) = 10 mL; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 4-MDBT = 4-methyldibenzothiophene; BT = benzothiophene	DBT, 4,6-DMDBT and 4-MDBT removal efficiency of 100 % within 60 min; Th and BT removal efficiency of 91.8 % and 96 % within 120 min, respectively; k(DBT) = 0.1071 min^{-1}	7	[42]
$[Cu_{12}(BTC)_8(H_2O)_{12}][H_5PMo^{VI}_{10}V^{V}_{2}O_{40}]@(H_2O)_{49}$ (**1**); $[Cu_{12}(BTC)_8(H_2O)_{12}][H_4PMo^{VI}_{11}V^{V}O_4]@(H_2O)_{30}$ (**2**); BTC = benzene-1,3,5-tricarboxylic acid or trimesic acid	Keggin	T = 65 °C; t = 5 h; m(catalyst) = 0.03 g; n(substrate) = 0.5 mmol; n(O)/n(S) = 6; $V(CH_2Cl_2)$ = 5 mL; DBT = dibenzothiophene	DBT removal efficiency of 89.6 % (**1**) and 85.8 % (**2**) within 5 h	4	[43]
$[PMo^{VI}_{12}O_{40}]^{3-}$/Ti-TUD-1; Ti-TUD-1 = titanium-containing mesoporous silica material	Keggin	T = 70 °C; t = 2 h; m(gas oil) = 40 g; m(H_2O_2 30 % aq) = 14 g; H_2O_2 – oxidant; m(catalyst) = 2 g; solvent – toluene; extraction solvent – methanol; V(MeOH) = 40 mL; $n(H_2O_2)/n(S)$ = 10	68 wt % of sulfur content removed at 70 °C within 2 h	3	[44]
Fe_3O_4@CS@POM; POM = PMo^{VI}_{12} > PW^{VI}_{12} > $P_2W^{VI}_{17}$ > $P_2W^{VI}_{18}$ > SiW^{VI}_{12}, CS = chitosan	Keggin	T = 60 °C; t = 60-90 min; m(catalyst) = 100 mg; model oil ([DBT] = 500 ppm in octane); V(model oil) = 20 mL; V(H_2O_2 30%) = 100 µL; H_2O_2 – oxidant; V(MeCN) = 20 mL; DBT = dibenzothiophene	DBT removal efficiency of 100 % within 90 min (k = 0.0761 min^{-1}) for POM = $[PMo_{12}O_{40}]^{3-}$	5	[45]
[(n-$C_4H_9)_4N)_7H_5Si_2W^{VI}_{18}Cd_4O_{68}$]@PVA; PVA = polyvinyl alcohol	sandwich type	T = 40 °C; model oil (500 ppm of Th or BT in n-heptane); V(model oil) = 50 mL; oxidant – 2:1 H_2O_2/acetic acid; V(oxidant) = 6 mL; m(catalyst) = 0.1 g; t = 2 h; BT = benzothiophene; Th = thiophene	BT and Th removal efficiency of 98 % and 97 % within 2 h, respectively	5	[46]
$[C_3SO_3Hnhm]_3PW^{VI}_{12}O_{40}$; $[C_3SO_3Hnhm]^+$ = organic sulfonic acid-functionalized heterocyclic ammonium cation	Keggin	T = 50 °C; t = 105 min; model oil (DBT in n-octane); n(O)/n(S) = 15; H_2O_2 – oxidant; solvent – DMF; DBT = dibenzothiophene	DBT removal efficiency of 99.4 wt % within 105 min	at least 6	[47]
50-DTA-$Mo^{VI}O$-TiO_2; $Mo^{VI}O$ = $[Mo^{VI}_6O_{19}]^{2-}$, 50-DTA = 50 % loading of dodecyltrimethylammonium	Lindqvist	T = 60 °C; t = 40 min; model oil ([DBT] = 500 ppm in n-octane); V(model oil) = 5 mL; m(catalyst) = 0.010 g; n(O/S) = 2; H_2O_2 – oxidant; V(H_2O_2, 30 %) = 11 µL; DBT = dibenzothiophene	DBT removal efficiency of 100 % within 40 min	7	[48]
$[mim(CH_2)_3COO]_3PW^{VI}$@UiO-66; $[mim(CH_2)_3COO]^+$ = methylimidazolium propionate derivative cation, UiO-66 = zirconium-based metal-organic framework	Keggin	T = 70 °C; t = 60 min; model oil (DBT in n-octane; [S] = 1000 ppm); V(model oil) = 5 mL; m(catalyst) = 40 mg; V(MeCN) = 4.5 mL; n(O/S) = 5; m(H_2O_2, 30 %) = 0.09 g; H_2O_2 – oxidant; DBT = dibenzothiophene	DBT removal efficiency of 100 % within 60 min	at least 10	[49]
TBA[PW^{VI}_{11}]; TBA = tetrabutylammonium	lacunary Keggin	T = 70 °C; t = 40-190 min; model diesel (BT, DBT, 4-MDBT and 4,6-DMDBT in n-octane, [S] = 2000 ppm); V(model diesel) = 1 mL; $n(H_2O_2/S)$ = 3; p = 1 atm; n(catalyst) = 3 µmol; $n(H_2O_2)$ = 0.24 mmol; H_2O_2 – oxidant; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 4-MDBT = 4-methyldibenzothiophene; BT = benzothiophene	complete desulfurization of multicomponent model diesel within 190 min	10	[50]
5%[$(C_6H_{13})_3PC_{14}H_{29}]_3PMo^{VI}_{12}O_{40}$/g-$C_3N_4$; g-$C_3N_4$ = graphitic carbon nitride	Keggin	T = 60 °C; t = 180 min; n(O/S) = 4; V(model oil) = 5 mL; m(catalyst) = 0.05 g; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	DBT and 4,6-DMDBT removal efficiency of 100 % and 94.8 % within 180 min, respectively	6	[51]
$[H_3PW^{VI}_{12}O_{40}]/ZrO_2$	Keggin	T = 60 °C; t = 2 h; model oil (DBT ([S] = 500 ppm, in 200 mL petroleum ether); V(model oil) = 20 mL; m(catalyst) = 0.05 g; solvent – MeCN; V(MeCN) = 10 mL; n(O/S) = 4; V(H_2O_2, 30 wt % aq) = 64 µL; H_2O_2 – oxidant; DBT = dibenzothiophene	complete removal of DBT within 2 h (k = 0.0421 min^{-1})	20	[52]

$[H_3PMo^{VI}_{12}O_{40}]/SiO_2$@C; SiO_2@C = silica (SiO_2) coated or supported on carbon (C) materials	Keggin	T = 40 °C; t = 3 h; model oil (800 ppm of DBT in n-octane); V(model oil) = 2 mL; V(MeCN) = 2 mL; n(H_2O_2, 30 wt %) = 0.15 mmol; H_2O_2 – oxidant; n(catalyst) = 0.002 mmol; DBT = dibenzothiophene	DBT removal efficiency of > 99 % within 3 h	5	[53]
POM/PIL/Gr; POM = $[(NH_4)_3Co(OH)_6Mo^{VI}_6O_{18}]$, PIL = poly(ionic) liquid, Gr = graphene	Anderson-Evans	T = 100 °C; t = 3 h; model oil (DBT, BT and 4,6-DMDBT in decahydronaphtalene, [S] = 500 ppm); V(model oil) = 20 mL; m(catalyst) = 10 mg; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; BT = benzothiophene	DBT, BT and 4,6-DMDBT removal efficiency of 100 %, 72.5 % and 100 % within 3 h, respectively	6	[54]
$C_3H_4N_2$-$[H_3PW^{VI}_{12}O_{40}]$@CTS; CTS = chitosan	Keggin	T = 35 °C; t = 1 h; CH_3COOH:H_2O_2 (v/v = 2:1) as oxidant; V(oxidant) = 6 mL; model oil (DBT, BT and Th in n-heptane, [S] = 500 ppm); V(model oil) = 50 mL; V(MeCN) = 10 mL; DBT = dibenzothiophene; BT = benzothiophene; Th = thiophene	Th, BT and DBT removal efficiency of 96 %, 97 % and 97 % within 1 h, respectively	5	[55]
IMo^{VI}_6@iPAF-1; IMo^{VI}_6 = $[Na_5[IMo^{VI}_6O_{24}]\cdot 3H_2O]$, iPAF-1 = ionic porous aromatic framework	Anderson-Evans	T = 90-100 °C; t = 5-6 h; O_2 – oxidant; m(catalyst) = 10-20 mg; model oil (500 mg/L DBT in 6 mL decalin); V(diesel or gasoline) = 10 mL; DBT = dibenzothiophene	-model oil: DBT removal efficiency of 100 % at 90 °C within 5 h; -real gasoline and diesel: sulfur removal of 99.3 % and 99.4 % at 100 °C within 6 h, respectively	9	[56]
1.5HPA@MOF-199@CA; HPA = $[H_3PMo^{VI}_6W^{VI}_6O_{40}\cdot nH_2O]$, MOF-199 = porous copper-based MOF platform, CA = carbon aerogel	Keggin	T = 40 °C; t = 3 h; O_2 – oxidant; [catalyst] = 1.8 g/L; model oil (thiophene in n-octane, [S] = 1000 ppm); V(model oil) = 50 mL	sulfur removal efficiency of 99.23 % within 3 h (k = 1.655 h^{-1})	10	[57]
Fe_3O_4@NH_2-MIL-101-POM; POM = $[H_3PMo^{VI}_6W^{VI}_6O_{40}]$, NH_2-MIL-101 = metal-organic framework with amino groups (NH_2)	Keggin	T = 50 °C; t = 60 min; air flow rate = 1000 L/min; model oil (DBT in n-dodecane, [S] = 2000 ppm); [catalyst] = 0.7-0.8 g/L; DBT = dibenzothiophene	DBT removal efficiency of 100 % in 60 min	15	[58]
Cu-SPOM@PbO@PVA; Cu-SPOM = $Na_{13}[(CuW^{VI}_9O_{34})_2H_3Cu_4(H_2O)_2]\cdot 39H_2O$, PVA = polyvinyl alcohol	lacunary Keggin	T = 35 °C; t = 1 h; model oil (Th (500 ppm), BT (500 ppm) and DBT (500 ppm) in n-heptane); V(model oil) = 50 mL; V(H_2O_2/CH_3COOH, v/v 2:1) = 3 mL; H_2O_2/CH_3COOH – oxidant; real gasoline ([S] = 4996 ppmw); m(catalyst) = 0.1 g; DBT = dibenzothiophene; BT = benzothiophene; Th = thiophene; ppmw = parts per million by weight	Model oil: Th, BT and DBT removal efficiencies of 97 %, 98 % and 98 % within 1 h, respectively; Real gasoline: sulfur removal efficiency of 97 % within 1 h	5	[59]
[β-$SiMo^{VI}_3W^{VI}_9O_{40}$]@1-CCNF; 1-CCNF = 1-dimensional carbon chain nanofibers	Keggin	T = 60 °C; t = 2 h; model oils (500, 1000 and 2000 ppm of DBT, BT and 4,6-DMDBT in heptane); m(catalyst) = 10 mg; V(model oil) = 5 mL; V(H_2O_2, 30 wt %) = 50 µL; H_2O_2 – oxidant; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; BT = benzothiophene	DBT, BT and 4,6-DMDBT removal efficiencies of 99, 89 and 100 % within 2 h, respectively	at least 3	[60]
$[H_3PW^{VI}_{12}O_{40}]/SiO_2$	Keggin	T = 30 °C; t = 100 min; H_2O_2 – oxidant; model oils ([S] = 500 mg/L, DBT, BT or 4,6-DMDBT in petroleum ether); V(model oil) = 10 mL; m(catalyst) = 0.1 g; V(MeCN) = 10 mL; V(H_2O_2, 30 wt %) = 63 µL; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; BT = benzothiophene	complete removal of DBT within 100 min at 30 °C	6	[61]
SmPOM@TMA-LPMS; SmPOM = $[Sm(PMo^{VI}_{11}O_{39})_2]^{11-}$, TMA-LMPS = trimethylammonium-functionalized (TMA) large-pore mesoporous silica spheres (LMPS)	Keggin sandwich-type	T = 70 °C; t = 1-2 h; n(H_2O_2/S) = 13-16; real diesel ([S] = 23100 ppm); H_2O_2 – oxidant; model diesel (BT, DBT, 4-DMDBT and 4,6-DMDBT in n-octane, [S] =2100 ppm); extractant system – model diesel/[BMIM]PF_6 (v/v = 1:1); DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; BT = benzothiophene; 4-DMDBT = 4-methyldibenzothiophene; [BMIM]PF_6 = 1-	a) Model diesel: complete desulfurization within 1 h; b) Real diesel: sulfur removal of 74 % in 2 h	3	[62]

		butyl-3-methylimidazolium hexafluorophosphate			
[PMoV]@CuO@PAN; PMoV = $K_4[PMo^{VI}_{11}V^{V}O_{40}]$, PAN = polyaniline	Keggin	T = 35 °C; t = 1 h; model oil (500 ppmw of Th, BT and DBT in n-heptane); V(model oil) = 50 mL; 700 rpm; V(oxidant) = 3 mL; oxidant – H_2O_2/acetic acid (v/v = 2:1); solvent – MeCN; m(catalyst) = 0.1 g; V(MeCN) = 10 mL; DBT = dibenzothiophene; BT = benzothiophene; Th = thiophene; ppmw = parts per million by weight	a) Th, BT and DBT removal efficiency of 96 %, 97 % and 97 % respectively b) Real gasoline- sulfur removal efficiency of 96 % within 1 h	5	[63]
$[PW^{VI}_{11}]$@TMA-SBA-15 and $[PW_{11}]$@TMA-PMOE; $[PW_{11}] = [PW^{VI}_{11}O_{39}]^{7-}$, TMA-SBA-15 = SBA-15 aminosilylated mesoporous silica (SBA-15) functionalized with trimethylammonium groups, TMA-PMOE = trimethylammonium-functionalized (TMA) periodic mesoporous organosilica (PMOE)	Keggin	T = 70 °C; t = 60 min; model oil (500 ppm of 1-BT, DBT, 4-MDBT and 4,6-DMDBT in n-octane, [S] = 2000 ppm); n(POM) = 3 µmol; biphasic system: 1:1 of model diesel/MeCN (V = 1.5 mL); oxidant – H_2O_2; V(H_2O_2, 30 %) = 40 µL; n(H_2O_2/S) = 4; solvent-free experiments: V(model diesel) = 750 µL; n(H_2O_2) = 3 µmol; n(H_2O_2/S) = 4; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 1-BT = 1-benzothiophene; 4-DMDBT = 4-methyldibenzothiophene	a) Complete conversion of DBT, 4-MDBT and 4,6-DMDBT within 30 min under solvent-free system (both catalyst); for 1-BT: removal efficiency of 99.6 % within 60 min only with PW_{11}@TMA-SBA-15 b) Biphasic system: sulfur removal efficiency of 93.1 % with PW_{11}@TMA-SBA-15	max. 6	[64]
$[PMo^{VI}_{11}Cu]$@$MgCu_2O_4$@CS; CS = chitosan, $[PMo^{VI}_{11}Cu] = [PMo^{VI}_{11}CuO_{40}]^{5-}$	Keggin	T = 35 °C; t = 1 h; m(catalyst) = 0.1 g; oxidant – CH_3COOH/H_2O_2; V(oxidant) = 3 mL; extraction solvent – MeCN; V(solvent) = 10 mL; V(fuel) = 50 mL; DBT = dibenzothiophene; BT = benzothiophene; Th = thiophene	a) DBT, BT and Th removal efficiencies of 99 %, 98 % and 97 % within 1 h, respectively b) Real gasoline – sulfur removal efficiency of 98 %	5	[65]
$[PW^{VI}_{11}Zn]$@aptesSBA-15; aptesSBA-15 = amino-functionalized ((3-aminopropyl)triethoxysilane (aptes)) mesoporous silica (SBA-15), $[PW^{VI}_{11}Zn] = [PW^{VI}_{11}ZnO_{39}]^{5-}$	Keggin	T = 70 °C; t = 60 min; oxidant – H_2O_2; solvent-free: n(H_2O_2/S) = 4; biphasic: n(H_2O_2/S) = 8; model diesel (1-BT, DBT, 4-MDBT and 4,6-DMDBT in n-octane, [S] = 2000 ppm); p = 1 atm, extraction solvent – MeCN; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 1-BT = 1-benzothiophene; 4-DMDBT = 4-methyldibenzothiophene	a) Solvent-free: complete desulfurization within 60 min; b) Biphasic system: 97 % of desulfurization within 60 min	5	[66]
$[PMo^{VI}_{12}O_{40}]$@PPy-MSN, $[BPy]_3[PMo^{VI}_{12}O_{40}]$ and $[BMIM]_3[PMo^{VI}_{12}O_{40}]$; PPy-MSN = polypyrrole-coated mesoporous silica nanoparticles, [BPy] = 1-butylpyridinium cation, $[BMIM]^+$ = 1-butyl-3-methylimidazolium cation	Keggin	T = 70 °C; t = 3 h; n(POM) = 3 µmol; oxidant – H_2O_2; V(H_2O_2) = 75 µL; n(H_2O_2)/n(S) = 11; 1:1 model diesel/[BMIM][PF_6] ionic liquid; model oil (1-BT, DBT, 4-MDBT and 4,6-DMDBT in n-octane, [S] = 2350 ppm); DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 1-BT = 1-benzothiophene; 4-DMDBT = 4-methyldibenzothiophene	sulfur removal efficiency of 98 % within 3 h	3	[67]
(TBA)$[PW^{VI}Fe]$/PVA/CTS; (TBA)PWFe = (*n*-$C_4H_9)_4N)_4[PW^{VI}_{11}Fe(H_2O)O_{39}]$, PVA = polyvinyl alcohol, CTS = chitosan	Keggin	T = 60 °C; t = 2 h; model oil (BT, DBT, 4-MDBT and 4,6-DMDBT in n-heptane, [S] = 500 ppm); V(model oil) = 50 mL; oxidant – H_2O_2/acetic acid (v/v = 1:1); V(oxidant) = 6 mL; m(catalyst) = 0.1 g; extraction solvent – MeCN; V(MeCN) = 10 mL; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 4-DMDBT = 4-methyldibenzothiophene	a) Gas oil: sulfur removal efficiency of 97 % in 2 h b) Model oil: BT, DBT, 4-MDBT and 4,6-DMDBT removal efficiency of 96 %, 98 %, 97 % and 97 %, respectively	5	[68]
$[Ni_2Cl(TMR4A)_2(CH_3CN)_2]\cdot[PMo^{VI}_{12}O_{40}]\cdot 4CH_3CN$ and $[Co_2Cl(TMR4A)_2(CH_3CN)_2]\cdot[PMo^{VI}_{12}O_{40}]\cdot 4CH_3CN$; TMR4A = resorcin[4]arene-based ligand	Keggin	T = 50 °C; t = 3-14 h; n(catalyst) = 2 µmol; oxidant – TBHP; n(TBHP) = 1 mmol; n(substrate) = 0.4 mmol; V(CH_2Cl_2) = 5 mL; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; THBP = tert-butyl hydroperoxide	Removal efficiencies of both catalysts: MBT – 100% conversion within 3 h; DBT – 99 % conversion within 10 h; 4,6-DMDBT – 88 % conversion within 14 h and BT – 69 % within 14 h	5	[69]
		T = 60 °C; t = 120 min; m(catalyst) = 0.02 g; n(O/S) = 2; model fuel (DBT, BT or 4,6-DMDBT in petroleum ether, [S] = 1000			

		µg/g); V(model oil) = 20 mL; V(MeCN) = 20 mL; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene			
$[PW^{VI}_{11}]$@aptesSBA-15; $[PW^{VI}_{11}] = [PW^{VI}_{11}O_{39}]^{7-}$, aptesSBA-15 = amino-functionalized ((3-aminopropyl)triethoxysilane (aptes)) mesoporous silica (SBA-15)	lacunary Keggin	T = 70 °C; t = 1 h; model diesel (500 ppm of 1-BT, DBT, 4-MDBT and 4,6-DMDBT in n-octane); biphasic system: 1:1 diesel/MeCN; oxidant – H_2O_2; n(O/S) = 8; n(POM) = 3 µmol; real diesel ([S] = 2300 ppm); n(O/S) = 4; t= 2 h; 1-BT = 1-benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 4-DMDBT = 4-methyldibenzothiophene	a) Model oil – complete desulfurization of within 1 h; b) Real diesel: sulfur removal efficiency of 83.4 % within 2 h	8	[71]
$(DODMAC)_3Co(OH)_6Mo^{VI}_6O_{18}\cdot 3H_2O$; DODMAC = dodecyltrimethylammonium chloride surfactant	Anderson-Evans	T = 90 °C; t = 6 h; oxidant – O_2; flow rate = 60 mL/min; biphasic system – model diesel/$[Opy]BF_4$; model diesel (DBT, 4-DMDBT or 4,6-DMDBT in decalin, [S] = 500 ppm); V(model oil) = 20 mL; m(catalyst) = 10 mg; V($[Opy]BF_4$)/V(model oil) = 1:5; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 4-DMDBT = 4-methyldibenzothiophene; $[Opy]^+$ = 1-octylpyridinium cation	complete removal of DBT within 6 h	7	[72]
$K_6[\alpha\text{-}P_2W^{VI}_{18}O_{62}]\cdot 14H_2O$/mGO; mGO = modified graphene oxide	Wells-Dawson	T = 60 °C; m(catalyst) = 0.5 wt %; t = 300 min; model oil (DBT, BT and 4,6-DMDBT in n-octane); V(model oil) = 60 mL; oxidant – O_2; flow rate = 200 mL/min; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	sulfur removal efficiency of 96.10 % within 300 min	5	[73]
$(NH_4)_3Co(OH)_6Mo^{VI}_6O_{18}$/*p*-TsOH/PEG4000 (1:2); *p*-TsOH = para-toluenesulfonic acid, PEG4000 = polyethylene glycol with average molecular weight 4000	Anderson-Evans	T = 60 °C; t = 1 h; model diesel ([S] = 500 ppm); V(model diesel) = 20 mL; V(DES) = 4 mL; m(catalyst) = 20 mg; p = 1 atm; oxidant – O_2; flow rate = 60 mL/min; solvent – MeCN; DBT = dibenzothiophene; DES = deep eutectic solvent	DBT removal efficiency of 99 % in 1 h	5	[74]
$[C_7H_7(CH_3)_3N]_9PW^{VI}_9O_{34}$	Keggin	T = 60 °C; m(catalyst) = 0.2015 g; n(O/S) = 10; oxidant – H_2O_2; t = 3 h; model oil (DBT in n-octane; $[S]_0$ = 500 ppm); m(H_2O_2) = 0.749 g; DBT = dibenzothiophene	DBT removal efficiency of 100 % within 3 h	4	[75]
$Fe_2W_{18}Fe_4$@NiO@CTS; $Fe_2W_{18}Fe_4 = Na_9K[(FeW^{VI}_9O_{34})_2Fe_4(H_2O)_2]\cdot 32H_2O$), CTS = chitosan	sandwich-type	T = 35 °C; t = 60 min; model oil (Th, BT and DBT in n-heptane, [S] = 500 ppm); V(model oil) = 50 mL; m(catalyst) = 0.1 g; oxidant – H_2O_2/acetic acid (v/v = 2:1); V(oxidant) = 3 mL; V(MeCN) = 10 mL; Th = thiophene; BT = benzothiophene; DBT = dibenzothiophene	a) Gasoline: sulfur removal efficiency of 97 % within 60 min; b) Model oil: Th, BT and DBT removal efficiencies of 97 %, 98 % and 99 %, respectively	5	[76]
$[PyPS]_3(NH_4)_3Mo^{VI}_7O_{24}$; [PyPS] = pyridylphosphinosulfonate	heptamolybdate	T = 25 °C; m(catalyst) =10 mg; t = 60 min; n(H_2O_2)/n(S) = 3, V(H_2O_2) = 0.053 mL; oxidant – H_2O_2; V_{IL}/V_{Oil} = 1/10; V($[Omim]BF_4$) = 1 mL; model oil (DBT in n-octane); real diesel: V(H_2O_2) = 2 mL; m(catalyst) = 0.2 g; T = 80 °C; t = 4 h; DBT = dibenzothiophene; $[Omim]^+$ = 1-methyl-3-octylimidazolium cation; IL = ionic liquid	a) DBT removal efficiency of 99% within 60 min; b) Real diesel: sulfur removal efficiency of 96 %	5	[77]
POM-PMI_n; POM = $[\beta\text{-}Mo^{VI}_8O_{26}]^{4-}$, PMI_n = poly(2,*p*-methylphenylionene)	octamolybdate	T = 50 °C; t = 2 h; m(catalyst) = 40 mg; model oil (BT, DBT and 4,6-DMDBT in n-octane ([S] = 250, 500 or 1000 ppm)); m(model oil)= 10 g; n(H_2O_2/S) = 5; V(MeCN) = 10 mL; oxidant – H_2O_2; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	DBT removal efficiency of 98.9 % within 2 h	6	[78]

3DOM HPW/Al–TiO_2; HPW = $[H_3PW^{VI}_{12}O_{40}]$, 3DOM HPW/Al–TiO_2 = three-dimensionally ordered macroporous (3DOM) alumina (Al) doped phosphotungstic acid (HPW)-TiO_2 material	Keggin	T = 60 °C; m(catalyst) = 0.03 g; n(O/S) = 4; t = 1 h; oxidant – H_2O_2; [S] = 500 ppm; V(model oil) = 10 mL; V(MeCN) = 10 mL; DBT = dibenzothiophene	DBT removal efficiency of 99.7 % within 1 h	6	[79]
PMo_{12}@TBA-MSN; $PMo_{12} = [PMo^{VI}_{12}O_{40}]^{3-}$, TBA-MSN = tetrabutylammonium-functionalized (TBA) mesoporous silica nanoparticles (MSN)	Keggin	T = 70 °C; t = 2 h; model oil (1-BT, DBT,4-MDBT and 4,6-DMDBT in n-octane, [S] = 2016 ppm); n(catalyst) = 3 µmol; n(O/S) = 13; V(H_2O_2) = 75 µL; oxidant – H_2O_2; extraction solvent – MeCN; 1-BT = 1-benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 4-DMDBT = 4-methyldibenzothiophene	complete desulfurization of model oil within 2 h	3	[80]
40 % HPW-GO; 40 % HPW = 40 % (wt %) of $[H_3PW^{VI}_{12}O_{40}]$, GO = graphene oxide	Keggin	T = 60 °C; t = 30-60 min; oxidant – H_2O_2; extraction solvent – MeCN; n(O/S) = 6; [catalyst] = 5 g/L; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	complete removal of DBT and 4,6-DMDBT within 30 min and complete removal of BT within 60 min	8	[81]
TBA-$Si_2W^{VI}_{18}Mn_4$@SAB; TBA-$Si_2W^{VI}_{18}Mn_4$ = $(n\text{-}C_4H_9)_4N)_7H_5[(SiW^{VI}_9O_{34})_2Mn^{II}_4(H_2O)_2]$, SBA = mesoporous silica material	sandwich-type	T = 35 °C; t = 1 h; CH_3COOH/H_2O_2 – oxidant; V(oxidant) = 3 mL; m(catalyst) = 0.1 g; model fuel (DBT, BT and Th in n-heptane, [S] = 500 ppm); V(model fuel) = 50 mL; solvent – MeCN; V(MeCN) = 10 mL; BT = benzothiophene; DBT = dibenzothiophene; Th = thiophene	a) Real gasoline: sulfur removal efficiency of 97 % within 1 h; b) Model fuel: DBT, BT and Th removal efficiency of 98 %, 97 % and 96 %, respectively	5	[82]
$[(C_6H_{13})_3P(C_{14}H_{29})]_3PMo^{VI}_{12}O_{40}$ /ChCl/2Ac; ChCl = choline chloride, Ac = acetate	Keggin	T = 50 °C; t = 120 min; model oil ([S] = 500 ppm in n-octane); V(model oil) = 5 mL; oxidant – H_2O_2; n(catalyst) = 0.0156 mmol; n(O)/n(S) = 4; V(ChCl/2Ac) = 2.5 mL; DBT = dibenzothiophene; 4-MDBT = 4-methyldibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	DBT, 4-MDBT and 4,6-DMDBT removal efficiencies of 97.2 %, 80.7 % and 76.0 % within 2 h, respectively	5	[83]
HPA–GO; HPA = $[H_3PMo^{VI}_{12}O_{40}]$, $[H_3PMo^{VI}_8W^{VI}_4O_{40}]$, $[H_3PMo^{VI}_6W^{VI}_6O_{40}]$, or $[H_3PW^{VI}_{12}O_{40}]$; GO = graphene oxide	Keggin	T = 50 °C; t = 30 min; catalyst loading: 2.4 g L^{-1}; n(O/S) = 6; extraction solvent – MeCN; [S] = 500 ppm or 1000 ppm	sulfur removal efficiency of 100 % ([S] = 500 ppm) and 97.5 % ([S] = 1000 ppm) within 30 min	nsp	[84]
$[C_4mim]_3PMo^{VI}_{12}O_{40}/SiO_2$; $[C_4mim]^+$ = 1-butyl-3-methylimidazolium cation	Keggin	m(catalyst) = 0.01 g; T = 60 °C; t = 60 min; n(O/S) = 3; model oil (BT, DBT, 4-MDBT and 4,6-DMDBT in n-octane, [S] = 250 ppm); V(model oil) = 5 mL, oxidant – H_2O_2; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; 4-DMDBT = 4-methyldibenzothiophene	sulfur removal efficiency of 100 %	7 (7 % activity loss)	[85]
$FeW^{VI}_{11}V$@CTAB-MMT; $FeW^{VI}_{11}V = [Fe^{III}W^{VI}_{11}V^{V}O_{40}]^{7-}$, CTAB-MMT = cetyltrimethylammonium bromide-modified montmorillonite	Keggin	T = 35 °C; t = 1 h; m(catalyst) = 0.10 g; V(oxidant) = 3 mL; oxidant – HOAc/H_2O_2; extraction solvent – MeCN; model oil (Th, BT and DBT in n-heptane, [S] = 500 ppmw); V(gasoline) = 50 mL; BT = benzothiophene; DBT = dibenzothiophene; Th = thiophene; ppmw = parts per million by weight	BT, DBT and Th removal efficiencies of 98 %, 99 % and 97 % within 1 h, respectively gasoline: sulfur removal efficiency of 97 % within 1 h	5	[86]
$[C_nmim]_3H_3V^{V}_{10}O_{28}$/g-BN; n = 8, 12, 16; $[C_nmim]$ = 1-cyanomethyl-3-methylimidazolium, g-BN = graphitic boron nitride	decavanadate	T = 120 °C; t = 4 h; m(catalyst) = 0.08 g; model oil ([S] = 500 ppm); V(model oil) = 40 mL; oxidant – air; flow rate = 100 mL/min; DBT = dibenzothiophene	DBT removal efficiency of up to 99.8 % within 4 h	6 (0.4 % activity loss)	[87]
42 % PTA@MOF-808A; 42 % PTA = 42 % (wt %) loading of $[H_3PW^{VI}_{12}O_{40}]$, MOF-808A = zirconium-based metal-organic framework	Keggin	T = 60 °C; t = 30 min; m(catalyst) = 12 mg; extraction solvent – MeCN; V(MeCN) = 2 mL; model oil ([S] = 1000 ppm); V(model oil) = 2 mL; oxidant – H_2O_2; V(H_2O_2) = 21 µL	complete desulfurization within 30 min (k = 0.16 min^{-1})	at least 5	[88]

CNTs@MOF-199-$Mo_{16}V_2$; $Mo_{16}V_2$ = $[H_8P_2Mo^{VI}_{16}V^{V}_{2}O_{62}\cdot mH_2O)$, CNTs = carbon nanotubes, MOF-199 = copper-based metal-organic framework	Wells-Dawson	T = 80 °C; t = 180 min; m(catalyst) = 0.12 g; model oil (2.87 g DBT in 250 mL n-octane, [S] = 2000 ppm); V(model oil) = 50 mL; oxidant – O_2; flow rate = 1.5 L/min; DBT = dibenzothiophene	DBT removal efficiency of 98.30 % within 180 min	7	[89]
PMo/BzPN-SiO_2; PMo = $[PMo^{VI}_{12}O_{40}]^{3-}$, BzPN-$SiO_2$ = benzyl-modified porous silica (SiO_2)	Keggin	T = 60 °C; t = 3 h; p = ambient pressure; model oil (DBT, BT or 4,6-DMDBT (0.50 mmol) in heptane (10 mL)); n(POM) = 0.0056 mmol; oxidant – 30% H_2O_2; n(H_2O_2) = 1.51 mmol; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	100 % of DBT and 4,6-DMDBT conversion	nsp	[90]
$[H_8PV^{V}_{5}Mo^{VI}_{7}O_{40}]$	Keggin	T = 120 °C; t = 12 h; n(oxalic acid) = 0.5 mmol; n(POM) = 0.5 mmol in 100 mL of H_2O; model oil (0.25 mmol of DBT in 10 mL n-tetradecane); p = 20 bar; oxidant – O_2; DBT = dibenzothiophene	complete desulfurization of model oil within 12 h	at least 5	[91]
$[C_nquin]_4Mo^{VI}_{8}O_{26}$, n = 2, 5, 8; $[C_nquin]^+$ = *N*-alkylquinolinium cation with alkyl chain lengths n = 2, 5, 8	octamolybdate	T = 60 °C; t = 90 min; n(H_2O_2)/n(DBT) = 4; n(DBT)/n(catalyst) = 100; model oil (500 ppm of S-compounds in n-dodecane); V(model oil) = 5 mL; V($[C_8mim]BF_4$) = 1 mL; $[C_8mim]BF_4$ – ionic liquid phase; DBT = dibenzothiophene; $[C_8mim]^+$ = 1-octyl-3-methylimidazolium cation	DBT removal efficiency of up to 99.2 % within 90 min	5 (4.8 % of activity loss)	[92]
PMo_{12}@MOF; PMo_{12} = $[PMo^{VI}_{12}O_{40}]^{3-}$, MOF = metal-organic framework NH_2-MIL-101(Cr)	Keggin	model diesel (S-compounds ([S] = 2000 ppm) in n-octane); V(model diesel) = 0.75 mL; oxidant – H_2O_2; T = 50 °C; extraction solvent – MeCN or $[BMIM][BF_6]$; n(POM) = 3 µmol; V(extracting solvent) = 0.75 mL; n(H_2O_2) = 0.30 mmol; t = 2 h; [BMIM] = 1-butyl-3-methylimidazolium	a) Real diesel: sulfur removal efficiency of 80 % within 2 h; b) Model diesel: sulfur removal efficiency of 95 %	3	[93]
POM@MOF-199@LZSM-5; POM = $[H_3PMo^{VI}_{6}W^{VI}_{6}O_{40}]$, MOF-199 = copper-based metal-organic framework, LZSM-5 = large pore size zeolite	Keggin	T = 60 °C; t =120 min; [catalyst] = 1.5 g/L; [S] = 2000 ppm; oxidant – O_2; flow rate = 1000 mL/min	complete desulfurization within 120 min	10 (8.96 % of activity loss)	[94]
$[Dda\text{-}pX]_2[\beta\text{-}Mo^{VI}_{8}O_{26}]$; [Dda-pX] = *N*,*N*-didodecylammonium with a *p*-substituted group "X" on the aromatic or alkyl chain	octamolybdate	T = 40 °C; t = 120 min; m(catalyst) = 40 mg; m(model oil) = 10 g; oxidant – H_2O_2; n(H_2O_2)/n(S) = 6; model oil (DBT in n-octane, [S] = 1000 ppm); DBT = dibenzothiophene	DBT removal efficiency of 99.7 % within 120 min	6	[95]
$[H_3PMo^{VI}_{12}O_{40}]$-GO; GO = graphene oxide	Keggin	T = 50 °C; t = 30 min; [catalyst] = 2.5 g/L; n(O/S) = 6; oxidant – H_2O_2; model oil (DBT in n-hexane, [S] = 500 ppm); V(model oil) = 5 mL; DBT = dibenzothiophene	complete desulfurization within 30 min	6	[96]
ODA_7PW_{11}; ODA^+ = octadecylammonium cation, PW_{11} = $[PW^{VI}_{11}O_{39}]^{7-}$	lacunary Keggin	T = 70 °C; t = 40 min; oxidant – H_2O_2; n(H_2O_2)/n(S) = 3 or 8; n(catalyst) = 3 µmol; model diesel ([S] = 500 ppm); V(model diesel) = 0.75 mL	complete desulfurization within 40 min	nsp	[97]
C@$PMo^{VI}_{10}V^{V}_{2}$; C = carbon composite, $PMo^{VI}_{10}V^{V}_{2}$ = $[H_5PMo^{VI}_{10}V^{V}_{2}O_{40}]$	Keggin	T = rt; t = 2 h; m(catalyst) = 1.4 x 10^{-4} g; V(H_2O_2) = 8 µl; solvent – EtOH:n-heptane (v/v = 1:1); model oil ([S] = 250, 500 or 1000 ppm); V(model oil) = 5 mL; rt = room temperature	sulfur removal efficiency of 94 % within 2 h	at least 4	[98]
$Cs_5[PM(H_2O)Mo^{VI}_{11}O_{39}]\cdot 5H_2O$; M = Co^{2+}, Ni^{2+}, Zn^{2+}, and Mn^{2+}	Keggin	T = 60 °C; t = 100 min; model oil (refractory S-compounds in n-octane, [S] = 500 ppm); V(model oil) = 5 mL; solvent – MeCN; V(MeCN) = 5 mL; oxidant – H_2O_2 30 %; n(catalyst) = 4 µmol; n(H_2O_2)/n(DBT) = 8; BT = benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene	for Co^{II}-POM: DBT, 4,6-DMDBT and BT removal efficiencies of 99.8 %, 92.9 % and 85.3 % within 100 min, respectively	at least 4	[99]
$PW_{11}Zn$@$BMIMPF_6$; $PW_{11}Zn$ = $TBA_4H[PW^{VI}_{11}Zn(H_2O)O_{39}]\cdot 5H_2O$, TBA = tetrabutylammonium	Keggin	T = 50 °C; t = 3 h; oxidant – H_2O_2; model oil (DBT, 1-BT and 4,6-DMDBT in n-octane, [S] = 500 ppm of each); biphasic system – model diesel/ $BMIMPF_6$ (v/v = 1:1); V(H_2O_2) = 30 µL;	a) Model diesel: complete desulfurization within 3 h; b) Real diesel: desulfurization	at least 3	[100]

$BMIMPF_6$ = 1-butyl-3-methylimidazolium hexafluorophosphate		1-BT = 1-benzothiophene; DBT = dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene			
$[cetrimonium]_{11}[P_2W^{VI}_{13}V^{V}_5O_{64}]$	Wells-Dawson	T= 60 °C; t = 60 min; [catalyst] = 7.5 g/L; n(O)/n(S) = 4; oxidant – H_2O_2/formic acid (n(O)/n(acid) = 1); model oil (500 ppmw of DBT and 500 ppmw of BT in isooctane); extracting solvent – MeCN; BT = benzothiophene; DBT = dibenzothiophene; ppmw = parts per million by weight	a) Model oil: DBT and BT removal efficiencies of 98 % and 82 %, respectively b) Real diesel: total sulfur removal efficiency of 90 %	8	[101]
$TBA_4[PW^{VI}_{11}Fe^{III}(H_2O)O_{39}]$@PbO; TBA = tetrabutylammonium	Lacunary Keggin	T = 60 °C; t = 2 h; oxidant – CH_3COOH/H_2O_2 (v/v = 1:1); model oil (aromatic sulfur compounds in n-heptane (BT, DBT, 4-MDBT and 4,6-DMDBT, [S] = 500 ppmw of each compound); V(model oil) = 50 mL; V(oxidant) = 6 mL; m(catalyst) = 0.1 g; V(MeCN) = 10 mL; BT = benzothiophene; DBT = dibenzothiophene; 4-MDBT = 4-methyl dibenzothiophene; 4,6-DMDBT = 4,6-dimethyldibenzothiophene; ppmw = parts per million by weight	a) Real gas oil: sulfur removal efficiency of 97 % after 2 h; b) Model oil: BT, DBT, 4-MDBT and 4,6-DMDBT removal efficiencies of 93 %, 97 %, 94 % and 95 %, respectively	5 (4 % of activity loss)	[102]
$(OTA)_3PW^{VI}_{11}SnO_{39}/TiO_2$; OTA = octadecyltrimethylammonium	Lacunary Keggin	T = 60 °C; t = 20 min; m(catalyst) = 0.02 g; n(O)/n(S) = 6; oxidant – H_2O_2; model oil ([S] = 500 ppm in n-octane); V(model oil) = 5 mL; V([BMIM]PF_6) = 1 mL; [BMIM]PF_6 = 1-butyl-3-methylimidazolium hexafluorophosphate; DBT = dibenzothiophene	DBT removal efficiency of 100 % within 20 min	7	[103]
$[PSPy]_3[PMo^{VI}_{12}O_{40}]$/GC; [PSPy] = *N*-(3-sulfonatepropyl)-pyridinium, GC = graphite carbon	Keggin	T = 50 °C; t = 60 min; model oil (500 ppmw of DBT in n-octane); V(model oil) = 5 mL; V(H_2O_2, 30 %) = 24 µL; n(O)/n(S) = 3; m(catalyst) = 0.05 g; DBT = dibenzothiophene; ppmw = parts per million by weight	DBT removal efficiency of 100 % within 60 min	6 (2.8 % of activity loss)	[104]
$[Na_3PW^{VI}_{12}O_{40}]$	Keggin	T = 70 °C; t = 30 min; model oil (500 ppm of DBT or BT in toluene); oxidant – H_2O_2; BT = benzothiophene; DBT = dibenzothiophene	DBT removal efficiency of 97.4 % within 30 min (k = 0.4008 min^{-1})	nd	[105]
[VimAm]Br–$PMo^{VI}_6W^{VI}_6O_{40}$@CA; CA = green fiber, [VimAm]Br = 1-vinyl-3-amyl imidazolium bromide	Keggin	T = 60 °C, t = 60 min; [catalyst] = 2.0 g/L; n(O/S) = 7; [S] = 1000 ppm; DBT = dibenzothiophene	DBT removal efficiency of 99.91 % within 60 min	5	[106]
HPW@HUSY; HPW = $[H_3PW^{VI}_{12}O_{40}]$, HUSY = H-type ultrastable Y zeolite	Keggin	T = 333 K; t = 120 min; model oil (500 ppm DBT in n-octane); V(model oil) = 20 mL; n(O/S) = 5; m(catalyst) = 0.1 g; DBT = dibenzothiophene	99.2 % DBT removal within 120 min	6	[107]
Mo_8/h-BN; Mo_8 = $[Mo^{VI}_8O_{26}]^{4-}$, h-BN = hexagonal boron nitride	octamolybdate	T = rt; t = 35 min; n(O/S) = 4; POM loading amount = 50 wt %; V([BMIM]BF_6) = 1 mL; [S] = 500 ppm; BMIMPF_6 = 1-butyl-3-methylimidazolium hexafluorophosphate; DBT = dibenzothiophene; rt = room temperature	100 % DBT conversion within 35 min	5	[108]
Fe_3O_4@CTS@PMoW; CTS = chitosan, PMoW = $PMo^{VI}_6W^{VI}_6O_{40}$	Keggin	Model oil (5 mL hexane with 500 ppm S-compounds); n(O/S) = 5; T = 60 °C; t = 120 min	99 % S-removal efficiency within 60 min	5	[109]
Fe_3O_4@CTS@HPWV; CTS = chitosan, HPWV = $H_{11}P_2W^{VI}_{13}V^{V}_5O_{62}$	Wells-Dawson		97 % S-removal efficiency within 60 min		
$PMo_{11}V$/NiO/PAN; $PMo_{11}V$ = $H_4PMo^{VI}_{11}V^{V}O_{40}$, PAN = polyaniline	Keggin	T = 35 °C; [S] = 500 ppm; t = 60 min; [catalyst] = 0.10 g; V(H_2O_2, 30 %) = 3 mL; V(MeCN) = 10 mL	97 % S-removal efficiency after 60 min	5	[110]
IL($CoMo_6$)-MIL-101-NH_2; $CoMo_6$ = $(NH_4)_3H_6CoMo^{VI}_6O_{24}$, Metal-organic framework = IL(Br)-MIL-101-NH_2	Anderson-Evans	T = 90 °C; t = 120 min; model oil ([S] = 500 ppm in n-octane); m(catalyst) = 20 mg; O_2 (1 atm, 60 mL/min); DBT = dibenzothiophene	100 % DBT removal efficiency within 120 min	6	[111]

HPW/H-β-TPAOH@TiO2@SiO2-T+S; H-β-TPAOH = tetrapropyl ammonium hydroxide H-β zeolite ($n(SiO_2/Al_2O_3)$ = 20.5), T+S = simultaneous titanium silylation treatment, HPW = $[PW^{VI}_{12}O_{40}]^{3-}$	Keggin	T = 50 °C; t = 1 h; $m_{oil}/m_{catalyst}$ = 35:1; n(O/S) = 13; model oil ([S] = 1100 ppmw in n-octane); DBT = dibenzothiophene; BT = benzothiophene; ppmw = parts per million by weight	99.9 % DBT and BT removal efficiency in 60 min	4	[112]
$PMo_{10}V_2$/APTES-HMSNS; $PMo_{10}V_2 = H_5PMo^{VI}_{10}V^{V}_2O_{40}$, APTES-HMSNS = 3-aminopropyltriethoxysilane - hollow mesoporous silica nanomaterials	Keggin	T = 60°C; t = 60 min; [catalyst] = 2.5 g/L; n(O/S) = 10; model oil ([S] = 2000 ppm in n-octane); DBT = dibenzothiophene	99.99 % DBT removal in 60 min	8	[113]
$[C_{12}mim]_3PW^{VI}_{12}O_{40}$/RE-UiO-66; RE = rare-earth metals (Y or La), UiO-66 = Zr-based metal-organic framework, $[C_{12}mim]$ = 1-dodecyl-3-methylimidazolium	Keggin	T = 60 °C; t = 40 min; n(O/S) = 5, m(catalyst) = 0.1 g; model oil ([S] = 500 μg/g); V(model oil) = 10 mL; V(MeCN) = 0.5 mL; DBT = dibenzothiophene	100 % DBT removal efficiency within 40 min	13	[114]
$n[H_3PW^{VI}_{12}$-MIL-101(Cr)]/$m(TiO_2)$, n/m = 1:5.78, MIL-101(Cr) = Cr-based metal-organic framework MIL-101	Keggin	T = 50 °C; n(O/S) = 4; t = 180 min, m(catalyst) = 0.02 g; model oil ([S] = 500 ppm in n-octane)	99 % desulfurization efficiency within 180 min	6	[115]
$[C_{16}mim]PMo^{VI}_{12}O_{40}$/MIL-101; $[C_{16}mim]$ = 1-hexadecyl-3-methylimidazolium, MIL-101 = Cr-based metal-organic framework	Keggin	$[C_{16}mim]Cl$ – ionic liquid; model oil ([S] = 200 ppm in n-octane); V(model oil) = 5 mL; m(catalyst) = 50 mg; T = 50 °C; n(O/S) = 5; DBT = dibenzothiophene	99.8 % DBT removal efficiency	8	[116]
p-C_4VIM-V_{10}; $V_{10} = [V^{V}_{10}O_{28}]^{6-}$ $[C_4VIM]$ = 1-vinyl-3-alkylimidazolium (ionic liquid)	decavanadate	T = 120 °C, t = 3 h; air flow = 100 mL/min; m(catalyst) = 0.05 g	98.8 % sulfur removal efficiency in 3 h	10	[117]
$P_2W_{18}Co_4$@$ZnFe_2O_4$@PVA PVA = polyviniyl alcohol, $P_2W_{18}Co_4 = [(PW^{VI}_9O_{34})_2Co_4(H_2O)_2]^{10-}$	sandwich-type	[S] = 100 ppm; UV lamp: 50 W Hg lamp, λ = 313 nm; t = 90 min; m (catalyst) = 0.03 g; BT = benzothiophene; DBT = dibenzothiophene	97 % BT and 94 % DBT removal efficiency in 90 min	5	[118]
Fe_3O_4@C@P_2W_{18}, $P_2W_{18} = [P_2W^{VI}_{18}O_{62}]^{6-}$, C = carbon composite	Wells-Dawson	T = 70 °C; t = 5 min; n(O/S) = 2; model oil ([S] = 2000 ppm in n-octane); m(catalyst) = 0.03 g	100 % sulfur removal efficiency within 5 min at 70 °C	12	[119]
PDC-PMo_{12}, PDC-Mo_8, and PDC-Mo_6; $PMo_{12} = H_3PMo^{VI}_{12}O_{40}$, $Mo_8 = [(n\text{-}C_4H_9)_4N]_4[\alpha\text{-}Mo^{VI}_8O_{26}]$, $Mo_6 = [(n\text{-}C_4H_9)_4N]_2[Mo^{VI}_6O_{19}]$, PDC = polyionic liquid (prepared from 3-propionic acid-1-vinylimidazolium bromine)	Keggin, Lindqvist and octamolybdate	T = 50 °C; t = 40 min; model oil ([S] = 500 ppm in n-octane); n(O/S) = 4; m(catalyst) = 10 mg; DBT = dibenzothiophene	PDC-PMo_{12}: 14.6 % DBT removal efficiency within 40 min; PDC-Mo_8: 100 % DBT removal efficiency within 40 min; and PDC-Mo_6: 52.4 % DBT removal efficiency within 40 min	5	[120]
$[C_{16}MIM]_4[PW^{VI}_{11}Fe^{III}(H_2O)O_{39}]$; $[C_{16}MIM]$ = 1-hexadecyl-3-methylimidazolium	Keggin	model oil ([S] = 500 ppm); t = 150 min; 1 % catalyst dosage (relative to model oil mass); T = 70 °C; H_2O_2 – oxidant; DBT = dibenzothiophene	98.54 % DBT removal efficiency in 150 min	5	[121]
$[H_2BBPTZ]_2Co(BBPTZ)_2[P_2W^{VI}_{18}O_{62}]\cdot 2H_2O$; BBPTZ = 4,4′-*bis*(1,2,4-triazol-1-ylmethyl)biphenyl	Wells-Dawson	T = 50 °C; t = 8-12 h; $V(CH_2Cl_2)$ = 5 mL; n(DBT) = 0.3 mmol; n(catalyst) = 0.075 mmol; n(tert-butyl hydroperoxide) = 2 mmol; DBT = dibenzothiophene	94.6 % DBT removal efficiency within 8 h	6	[122]
$[(Ni_2(TBTZ)_2(H_2O)_4][H_2P_2W^{VI}_{18}O_{62}]\cdot 17.5H_2O$; TBTZ = 1,3,5-*tris*(1,2,4-triazol-1-ylmethyl)-2,4,6-trimethyl benzene			98.3 % DBT removal efficiency within 8 h		

*nsp- not specified by authors

2. POMs and POM-based composites in the removal of various organic pollutants from water

Table S2 A Summary of published POMs and POM-based composites for application in the removal of various organic pollutants from water.

Formula	POM archetype	Pollutants	Conditions	Efficiency	Number of cycles	Ref
SiO_2@[*n*-$C_7H_{15})_4N]_8SiW^{VI}_{11}O_{39}^{8-}$	Keggin	PBV	[PBV] = 32 µM; amount of catalyst = 800 mg; PBV = dye patent blue V	95 %	nsp	[123]
PTMS-treated alumina/PEI-$PV^{V}_2Mo^{VI}_{10}O_{40}$; PTMS = 3-aminopropyl trimethoxysilane, PEI = polyetherimide	Keggin	RB5	[RB5] = 20 ppm; T = 25 °C; Operating time = up to 3 h; RB5 = reactive black 5	100 %	6	[124]
$K_6P_2W^{VI}_{18}O_{62}$@UiO-66; UiO-66 = Zr-based metal-organic framework	Wells-Dawson	RhB	[RhB] = 30 ppm; pH = 3; T = 25 °C; RhB = rhodamine B	99 % within 120 min, (k = 0.00438 g mg^{-1} min^{-1})	nsp	[125]
PW_{12}@MIL-101(Fe); PW_{12} = $[PW^{VI}_{12}O_{40}]^{3-}$, MIL-101(Fe) = Fe-based metal-organic framework	Keggin	MB	[MB] = 5 ppm; amount of catalyst = 10 mg/100 mL; MB = methylene blue	99.5 % within 30 min	3	[126]
$[Cu_2(btx)_2(C_2O_4)][H_2SiW^{VI}_{12}O_{40}]\cdot12H_2O$; btx = 1,4-bis(triazol-1-ylmethyl)benzene)	Keggin	MB	nsp; MB = methylene blue	78 % within 60 min, under visible light; 91 % within 60 min, under UV light	nsp	[127]
$[\{Cl_4Cu_{10}(pz)_{11}\}\{As_2W^{VI}_{18}O_{62}\}]\cdot1.5H_2O$; pz = pyrazine	Wells-Dawson	RhB	[RhB] = 10^{-5} M; amount of catalyst = 50 mg; light source = 250 W Hg lamp; RhB = rhodamine B	96.8 % within 80 min, (k = 0.005 min^{-1})	5	[128]
$(CH_3NH_2CH_3)[Cu_2(TPB)_2(PW^{VI}_{12}O_{40})]\cdot4DMF\cdot6H_2O$; TPB = 1,2,4,5-tetra(4-pyridyl)benzene	Keggin	MO, MB	[dye] = 10 ppm; amount of adsorbent = 50 mg; light source = 300 W Xe lamp; H_2O_2 = 2 ml (30 %); MB = methylene blue; MO = methyl orange	> 95 % MB removal within 120 min; 98.8 % MO removal within 120 min under visible light	nsp	[129]
$[NaP_5W^{VI}_{30}O_{110}]^{14-}$/MIL-101(Cr); MIL-101(Cr) = Cr-based metal-organic framework	Preyssler	MB	[MB] = 50 ppm; amount of catalyst = 30 mg; pH = 2; MB = methylene blue	100 % within 8 min, (k = 1.19 g mg^{-1} min^{-1})	4	[130]
$[P_2W^{VI}_{18}O_{62}]^{6-}$/$CoFe_2O_4$/MIL-101(Cr); MIL-101(Cr) = Cr-based metal-organic framework	Wells-Dawson	MB	[MB] = 100 ppm; amount of catalyst = 30 mg; pH = 6; T = 25 °C; MB = methylene blue	100 %	3	[131]
$H_6P_2W^{VI}_{18}O_{62}$@$Cu_3(BTC)_2$; BTC = trimesic acid	Wells-Dawson	MB	[MB] = 10 ppm; amount of catalyst = 20 mg/mL; MB = methylene blue	80 % within 60 min, (k = 0.0047 g mg^{-1} min^{-1})	nsp	[132]
$[PMo^{VI}_{12}O_{40}]$@$[Cu^{II}_6O(TZI)_3(H_2O)_9]_4\cdot OH\cdot31H_2O$ (**HLJU-1**) $[SiMo^{VI}_{12}O_{40}]$@$[Cu^{II}_6O(TZI)_3(H_2O)_9]_4\cdot32H_2O$ (**HLJU-2**) $[PW^{VI}_{12}O_{40}]$@$[Cu^{II}_6O(TZI)_3(H_2O)_6]_4\cdot OH\cdot31H_2O$ (**HLJU-3**); H_3TZI = 5-tetrazolylisophthalic acid	Keggin	RhB, CV	[RhB] = 9.5 ppm; [CV] = 15 ppm; amount of catalyst = 50 mg; RhB = rhodamine B; CV = crystal violet	> 60 % RhB removal and CV for HLJU-3, 80 % < for HLJU-1 and > 95 % for HLJU-2 within 360	5	[133]
$H_6P_2W_{18}O_{62}$/MOF-5; MOF-5 = Zn-based metal-organic framework	Wells-Dawson	MB	[MB] = 20 ppm; amount of catalyst = 15 mg/20 mL; MB = methylene blue	100 % within 10 min, (k = 0.2953 g mg^{-1} min^{-1})	nsp	[134]
FcSiW, Fc = ferrocene, SiW = $H_4SiW^{VI}_{12}O_{40}\cdot xH_2O$, x = nsp	Keggin	4-CP	amount of catalyst = 0.1 g L^{-1}; $[H_2O_2]$ = 10 mM; [4-CP] = 50 mg L^{-1}; pH = 6.5; light source = 250 W Hg lamp; T = 35 °C; 4-CP = 4-chlorophenol	100 % within 100 min under UV light; 97 % within 100 min in dark	3	[135]
			amount of catalyst = 50 mg; [Phenol] = 10	86.6 % within 300 min,		

			ppm; light source = 300 W Xe lamp; O_2 pressure = 0.1 MPa	(k = 0.0065 min^{-1})		
$[Ag_4(H_2pyttz\text{-}I)(H_2pyttz\text{-}II)(Hpyttz\text{-}II)][HSiW^{VI}_{12}O_{40}]\cdot 4H_2O$ (**1**) $[Ag_4(H_2pyttz\text{-}II)(Hpyttz\text{-}II)_2][H_2SiW^{VI}_{12}O_{40}]\cdot 3H_2O$ (**2**); H_2pyttz-I = 3-(pyrid-2-yl)-5-(1H-1,2,4-triazol-3-yl)-1,2,4-triazolyl; H_2pyttz-II = 3-(pyrid-4-yl)-5-(1H-1,2,4-triazol-3-yl)-1,2,4-triazolyl	Keggin	RhB	[RhB] = 10^{-5} M; amount of catalyst = 50 mg; light source = 125 W Hg lamp; RhB = rhodamine B	63.3 % removal for (**1**) within 150 min, (k = 0.006 min^{-1}); 81 % removal for (**2**) within 150 min, (k = 0.1 min^{-1})	nsp	[137]
per-6-deoxy-6-ethylenediamine-β-cyclodextrin/$H_3PW^{VI}_{12}O_{40}$	Keggin	RhB, MO, MB, XO, CV, NFZ, TCY, BE	[dye/antibiotic] = 1 mM; amount of catalyst = 0.055 mM POM + 0.03 mM EDA-CD; [H_2O_2] = 50 µL; light source = 50 W Hg lamp; RhB = rhodamine B; MB = methylene blue; MO = methyl orange; XO = xylenol orange; CV = crystal violet; NFZ = nitrofurazone; TCY = tetracyclines; BE = berberine	> 95 % removal efficiency of RhB within 4 min, (k = 0.868 ± 0.061 min^{-1}); > 95 % removal efficiency of XO within 15 min, (k = 0.214 ± 0.023 min^{-1}); > 95 % removal efficiency of MO within 20 min, (k = 0.164 ± 0.016 min^{-1}); > 95 % removal efficiency of MB within 30 min, (k = 0.119 ± 0.002 min^{-1}); > 95 % removal efficiency of CV within 35 min, (k = 0.084 ± 0.003 min^{-1}); > 95 % removal efficiency of NFZ within 19 min, (k = 0.163 ± 0.016 min^{-1}); > 95 % removal efficiency of TCY within 25 min, (k = 0.152 ± 0.016 min^{-1}); > 95 % removal efficiency of BE within 30 min, (k = 0.115 ± 0.007 min^{-1})	nsp	[138]
$[PW^{VI}_{12}O_{40}]^{3-}$	Keggin	lindane	[lindane] = 2.4 × 10^{-5} M; amount of catalyst = 7×10^{-4} M; pH = 1	100 % within 10 h	nsp	[139]
Fe_2O_3@SiO_2@$[n\text{-}C_7H_{15})_4N]_8SiW^{VI}_{11}O_{39}^{8-}$	Keggin	PBV	[PBV] = 32 µM; amount of catalyst = 50 mg; PBV = dye patent blue V	99 % within 24 h	nsp	[140]
$\{HCu^{II}$(N,N′-bis(2-pyrazinecarboxamide)-1,2-ethane)$[Cr^{III}Mo^{VI}_6(OH)_6O_{18}]\}\cdot 4H_2O$ (**1**) $[Cu^{II}_3$(N,N′-bis(2-pyrazinecarboxamide)-1,2-ethane)$_{0.5}(Te^{VI}Mo^{VI}_6O_{24})(H_2O)_9]$ (**2**)	Anderson-Evans	GV, MB, TB, MV	[dye] = 10 ppm; amount of catalyst = 50 mg; T = room temperature; GV = gentian violet; MB = methylene blue; TB = toluidine blue dye; MV = methylene violet	99 % GV removal for (1) and 71.43 % for (**2**); 95.63% MB removal for (**1**) and 81.25 % for (**2**); 90.65 % TB removal for (**1**) and 77.84 % for (**2**); 65.79 % MV removal for (**1**) and 44.87 % for (**2**)	4	[141]
$[(NH_4)_6(Mo^{VI}_7O_{24})]\cdot 4H_2O$	heptamolybdate	MB	[MB] = 220 ppm; amount of catalyst = 50 mg; pH = 1; T = 303 K; MB = methylene blue	> 97 % MB removal within 60 min, (k = 0.000234 min^{-1})	nsp	[142]
poly-[N,N-dimethyl-dodecyl-(4-vinylbenzyl)ammonium chloride]/($[Mo^{VI}_8O_{26}]^{4-}$)	octamolybdate	AR87	[AR87] = 200 ppm; T = 20 °C; AR87 = acid red 87	> 98 %	5	[143]
$\{HCu^{II}(HPCAP)_2[Cr^{III}Mo^{VI}_6(OH)_6O_{18}]\}\cdot 2H_2O$ (**1**) $\{Zn_4(PCAP)_2[Cr^{III}Mo^{VI}_6(OH)_6O_{18}]_2(H_2O)_{12}\}\cdot 4H_2O$ (**2**) $\{Zn_3(PCAP)_2[Cr^{III}Mo^{VI}_6(OH)_5O_{19}](H_2O)_6\}\cdot 6H_2O$ (**3**) $\{Ni^{II}_3(PCAP)_2[Ni^{II}Mo^{VI}_6(OH)_5O_{19}](H_2O)_6\}\cdot 8H_2O$ (**4**) $\{Cu^{II}_3(PCAP)_2[AlMo^{VI}_6(OH)_5O_{19}](H_2O)_6\}\cdot 6H_2O$ (**5**)	Anderson-Evans	GV, MB	[dye] = 10 ppm; amount of catalyst = 50 mg; GV = gentian violet; MB = methylene blue	96.9 % GV removal for (**1**), 97.9% for (**2**), 97.3 % for (**3**), 96.6 % for (**4**), 98.6 % for (**5**) and 97.1 % for (**6**), 87.3 % MB removal for (**1**), 92.1 % for (**2**), 93.8 % for (**3**), 94.4 %	nsp	[144]

$\{Co^{II}_3(HPCAP)_2[AlMo^{VI}_6(OH)_6O_{18}](H_2O)_{10}\}[AlMo^{VI}_6(OH)_6O_{18}]\cdot 6H_2O$ (**6**); HPCAP = 3-(2-pyridinecarboxylic acid amido)pyridine						
$[Ni^{II}(2,2'\text{-biimidazole})_3]_2[\beta\text{-}Mo^{VI}_8O_{26}]\cdot 8DMF$ (**1**) (dimethyl-ammonium)$_2[Ni^{II}(2,2'\text{-biimidazole})_2(H_2O)_2][\beta\text{-}Mo^{VI}_8O_{26}]\cdot 4DMF$ (**2**) (dimethyl-ammonium)$_2[Co^{II}(2,2'\text{-biimidazole})_2(H_2O)_2][\beta\text{-}Mo^{VI}_8O_{26}]\cdot 4DMF$ (**3**) $[Zn(2,2'\text{-biimidazole})(DMF)_3]_2[\beta\text{-}Mo^{VI}_8O_{26}]\cdot 2DMF$ (**4**) $[Cu^{II}(2,2'\text{-biimidazole})(DMF)_3]_2[\beta\text{-}Mo^{VI}_8O_{26}]\cdot 2DMF$ (**5**)	octamolybdate	MB	[MB] = 10 ppm; amount of catalyst = 15 mg; MB = methylene blue	> 80 % for compounds (**2**)-(**5**); < 10 % for (**1**) within 10 min	3	[145]
Fe_3O_4@$[Ni^{II}(2\text{-acetylpyridine-thiosemicarbazone})_2]_2H_2[P_2Mo^{VI}_5O_{23}]\cdot 4H_2O$ (**1**) Fe_3O_4@$[2\text{-acetylpyridine-thiosemicarbazone}]_5H[P_2Mo^{VI}_5O_{23}]\cdot 12H_2O$ (**2**)	Strandberg	MO, MB	[dye] = 15 ppm; amount of catalyst = 25 mg; MB = methylene blue; MO = methyl orange	94.8 % MB removal for (1) within 240 min, 97.67 % for (**2**) within 60 min; 13.13 % MO removal for (**1**) within 240 min and 8.84 % for (**2**) within 60 min	7	[146]
$[N(C_4H_9)_4]_3[Mn^{II}Mo^{VI}_6O_{18}\{(OCH_2)_3CN = CHC_6H_4OH\}_2]$/hexachlorocyclotriphosphazene	Anderson-Evans	AOG, PS, BF, MB	[MB] = 100 ppm; amount of catalyst = 0.125 mgL^{-1}; AOG = acid orange G; PS = ponceau S; BF = basic fuchsin; MB = methylene blue	98 % MB removal within 240 min, < 2 % AOG and PS removal and 95 % BF removal	nsp	[147]
$H_6P_2W^{VI}_{18}O_{62}$@Cu-BTC; BTC = trimesic acid	Wells-Dawson	TBBPA	[TBBPA] = 2 ppm; amount of catalyst = 40 mg; T = 298 K; TBBPA = tetrabromobisphenol-A	95 %, (k = 5.56 g mg^{-1} min^{-1})	6	[148]
aminopropylsilanized-$Co_3O_4/H_3PW^{VI}_{12}O_{40}$	Keggin	RhB, MO, MB	[dye] = 25 ppm; amount of catalyst = 20 mg; RhB = rhodamine B; MB = methylene blue; MO = methyl orange	98 % MB removal within 12 min, (k = 0.037 g mg^{-1} min^{-1}); 20 % RhB removal within 32 min; the removal efficiency of MO was negligible	3	[149]
NH_2-Fe_3O_4 /$[Cu^{II}(pca)_2(SiW^{VI}_{12}O_{40})](py)_2$; pca = pyridine-2-carboxylic acid; py = pyrazine	Keggin	TCY	pH = 6.8, TCY = tetracycline	88.6 %	5	[150]
$LaMnO_3$@SiO_2/PMo^{VI}_{12} (**1**) $LaMnO_3$@SiO_2/PW^{VI}_{12} (**2**) $LaMnO_3$@SiO_2/SiW^{VI}_{12} (**3**)	Keggin	MB	[MB] = 25 ppm; amount of catalyst = 25 mg; T = 25 °C; MB = methylene blue	100 % removal for (**1**) within 1 min, 98 % for (**2**) within 30 min and 100 % for (**3**) within 0.5 min	3	[151]
$LaNiO_3$@SiO_2/PW^{VI}_{12}	Keggin	MB	[MB] = 25 ppm; amount of catalyst = 30 mg; T = 25 °C; MB = methylene blue	98.5 % within 60 min, (k = 0.066 g mg^{-1} min^{-1})	3	[152]
m-phenylenediamine/$P_5W^{VI}_{30}$	Preyssler	MB	[MB] = 20 ppm; amount of catalyst = 5 mg; MB = methylene blue	> 95 % within 15 min	nsp	[153]
[Cd(pyridine-2-carbaldehyde semicarbazone)$_6$][pyridine-2-carbaldehyde semicarbazone]$^{+}_4[PMo^{VI}_{12}O_{40}]_4\cdot 18MeOH\cdot 4H_2O$	Keggin	RhB, MB	[dye] = 25 ppm; amount of catalyst = 30 mg; T = 25 °C; RhB = rhodamine B; MB = methylene blue	98 % MB removal within 5 min and 86 % RhB removal within 5 min	3	[154]
CuS@PANI/PW^{VI}_{12} (**1**) CuS@PANI/PMo^{VI}_{12} (**2**) CuS@PANI/SiW^{VI}_{12} (**3**); PANI = polyaniline	Keggin	MB	[MB] = 25 ppm; amount of catalyst = 25 mg; pH = 6; T = 25 °C; MB = methylene blue	93 % removal efficiency for (**1**) within 20 min (k = 0.0036 g mg^{-1} min^{-1}), 94 % for (**2**) within 0.5 min and 100 % for (**3**) within 2 min	4	[155]
amide-functionalized *N*-dodecyl-*N'*-acetamideimidazolium bromide/PW^{VI}_{12}	Keggin	RhB	[RhB] = 0.25 mM; amount of catalyst = 0.2 mg/mL; T = 25 °C; RhB = rhodamine B	100 % within 1 min	5	[156]

PW^{VI}_{12}/BEA zeolite; BEA = microporous crystalline aluminosilicate (zeolite)	Keggin	nicosulfuron	PW_{12}/zeolite weight ratio = 20 %; UltraSound = 30 min	adsorption capacity = 25.5 mg g^{-1}	nsp	[157]
POM−GA; POM = HSiW, GA = 3D graphene aerogels	Keggin	various water-soluble organic pollutants	reduction in N_2H_4; POM content = 30 % wt	absorption capacities = 100-210 g g^{-1}	10	[158]
$H_3K_2[Ag_5(DTB)_5][SiW^{VI}_{12}O_{40}]_2{\cdot}Cl_2{\cdot}8H_2O$; DTB = 1,4-di(1H-1,2,4-triazol-1-yl)benzene	Keggin	MB, BY, CV, Rh6G, RhB, EB*, CFB, MO	amount of catalyst = 20 mg; MB = methylene blue; BY = basic yellow 1; CV = crystal violet; Rh6G = rhodamine 6G; RhB = rhodamine B; EB*= eosin B; CFB = chromotrope FB; MO = methyl orange	74.33 % removal efficiency of CV; 84.94 % removal efficiency of MB; 40.51 % removal efficiency of BY; 30.23 % removal efficiency of Rh6G; 12.91 % removal efficiency of RhB; < 10 % removal efficiency for EB*, CFB, and MO within 90 min	nsp	[159]
NiAl-$SiW^{VI}_{12}O_{40}^{4-}$	Keggin	MG	[MG] = 12 ppm; amount of catalyst = 50 mg; MG = malachite green	94 % within 120 min, (k = 0.0218 g/mg min)	5	[160]
DODA·Br-$PV^{V}_{2}Mo^{VI}_{10}$/PVDF; DODA·Br = dimethyldioctadecylammonium bromide, $PV^{V}_{2}Mo^{VI}_{10}$ = $H_5[PV^{V}_{2}Mo^{VI}_{10}O_{40}]$, PVDF = polyvinylidene fluoride	Keggin	RB5	[RB5] = 15 ppm; amount of catalyst = 26 mg; T = 45 °C; RB5 = reactive black 5	97.5 % within 120 min	3	[161]
amine-functionalized graphene oxide/$PTi_2W^{VI}_{10}O_{40}^{7-}$	Keggin	RhB, MB	[dye] = 100 ppm; amount of catalyst = 10 mg; RhB = rhodamine B; MB = methylene blue	adsorption capacity of MB = 1095 mg g^{-1}; adsorption capacity of RhB = 540 mg g^{-1}	5	[162]
ZnAlFe-P_2W_{17} (**1**) ZnAlFe-CoW_{12} (**2**); P_2W_{17} = $[P_2W^{VI}_{17}]^{10-}$, CoW_{12} = $[CoW^{VI}_{12}]^{5-}$	Wells-Dawson, Keggin	MB	pH = 6.3; light source = 25 W Xe lamp; MB = methylene blue	< 10 % removal efficiency for (**1**) within 6 h and > 90 % for (**2**) within 6 h	nsp	[163]
$[C_{16}H_{33}(CH_3)_3N]H_4PMo^{VI}_{10}V^{V}_{2}O_{40}$	Keggin	DEP	[DEP] = 0.45 mM; amount of catalyst = 3.0 mM; $[H_2O_2]$ = 0.014 M; T = 25 °C; pH = 7.0; DEP = diethyl phthalate	90.2 % within 30 min	10	[164]
FePW/LDH (**1**) MnPW/LDH (**2**); LDH = layered double hydroxide, FePW = $[PFe^{III}W^{VI}_{11}O_{39}]^{4-}$, MnPW = $[PMn^{II}W^{VI}_{11}O_{39}]^{6-}$	Keggin	AR27	[AR27] = 20 ppm; amount of catalyst = 0.5 g/L; pH = 3; $[H_2O_2]$ = 0.2 mL/L; T = 40 °C; AR27 = acid red 27	98 % removal efficiency of AR27 for (**1**) within 30 min, and 99 % for (**2**) within 30 min	4	[165]
$PW^{VI}_{12}O_{40}^{3-}$-γ-Fe_2O_3/$SrCO_3$	Keggin	IBP	[IBP] = 10 ppm; amount of catalyst = 50 mg; light source = sunlight; IBP = ibuprofen	nsp	3	[166]
$KH[SiW^{VI}_{12}O_{40}][Ni^{II}(H_2O)_6]$cucurbit[6]uril·$7H_2O$	Keggin	MO	[MO] = 10 ppm; amount of catalyst = 0.5 gL^{-1}; pH = 2.5; $[H_2O_2]$ = 1.5 mmol L^{-1}; MO = methyl orange	95.6 % within 120 min	4	[167]
$Cs_3PMo^{VI}_{12}O_{40}$	Keggin	BR46	[BR46] = 10 ppm; amount of catalyst = 2 gL^{-1}; $[H_2O_2]$ = 2 mM; light source = 300 W Xe lamp; BR46 = basic red 46	100 % within 90 min	3	[168]
{[(Cu_4Cl)(4-(4-carboxyphenyl)-1,2,4-triazolate)$_4$]·$(HSiW^{VI}_{12}O_{40})$·$31H_2O$}	Keggin	RhB	[RhB] = 10 ppm; amount of catalyst = 15 mg; $[H_2O_2]$ = 2 mL (30%); light source = 300 W Xe lamp; RhB = rhodamine B	99 % within 80 min	3	[169]
$Na_3PW^{VI}_{12}O_{40}$/D201 resin; D201 = type I anion exchange resin	Keggin	RhB	[RhB] = 2 x 10^{-5} M; $[H_2O_2]$ = 2 x 10^{-3} M; pH = 2.5; light source = 500 W halogen lamp; RhB = rhodamine B	99 % within 240 min	7	[170]
$K_3PW^{VI}_{12}O_{40}$	Keggin	RhB	[RhB] = 2 x 10^{-5} M; amount of catalyst = 0.5 gL^{-1}; $[H_2O_2]$ = 2 x 10^{-3} M; pH = 2.1; light source = 500 W halogen lamp; RhB = rhodamine B	100 % within 150 min	7	[171]

$\{[Cu(en)_2]_{1.5}[Cu(en)(2,2'\text{-bipy})(H_2O)_n]Ce[(\alpha\text{-}PW^{VI}_{11}O_{39})_2]\}^{6-}$ (**1**) $\{[Cu(en)_2]_{1.5}[Cu(en)(2,2'\text{-bipy})(H_2O)_n]Pr[(\alpha\text{-}PW^{VI}_{11}O_{39})_2]\}^{6-}$ (**2**) $\{[Cu(en)_2]_2(H_2O)[Cu(en)(2,2'\text{-bipy})]Gd[(\alpha\text{-}HPW^{VI}_{11}O_{39})_2]\}^{4-}$ (**3**) $\{[Cu(en)_2]_2(H_2O)[Cu(en)(2,2'\text{-bipy})]Tb[(\alpha\text{-}HPW^{VI}_{11}O_{39})_2]\}^{4-}$ (**4**) $\{[Cu(en)_2]_2(H_2O)[Cu(en)(2,2'\text{-bipy})]Er[(\alpha\text{-}HPW^{VI}_{11}O_{39})_2]\}^{4-}$ (**5**) $\{[Cu(en)_2]_{1.5}[Cu(en)(2,2'\text{-bipy})]Nd[(\alpha\text{-}H_5PW^{VI}_{11}O_{39})_2]\}^{3-}$ (**6**); 2,2'-bipy =2,2'-bipyridine; en = ethylenediamine	Lacunary Keggin	RhB	[RhB] = 2 x 10^{-5} M; amount of catalyst = 2 x 10^{-6} mol; light source = 500 W Hg lamp; RhB = rhodamine B	26 % removal efficiency for (**1**), 34 % for (**2**), 29 % for (**3**), 35 % for (**4**) and 46 % for (**5**)	nsp	[172]
$H_3PW^{VI}_{12}O_{40}/ZrO_2$	Keggin	BCG, RhB, MO, MB, CV, 4-nitrophenol, DCP	[dye] = 10^{-5} M; amount of catalyst = 25 mg for dye degradation and 40 mg for herbicides; PW_{12}/ZrO_2 weight ratio = 1/3; light source = 50 W Hg lamp; BCG = bromo cresol green; RhB = rhodamine B; MO = methyl orange; MB = methylene blue; CV = crystal violet; DCP = 2,4- dichlorophenoxy acetic acid	78 % removal efficiency of MB within 70 min (k = 0.0218 min^{-1}); 99 % removal efficiency of RhB within 80 min (k = 0.0456 min^{-1}); 82 % removal efficiency of MO within 60 min (k = 0.0261 min^{-1}); 89 % removal efficiency of CV within 50 min (k = 0.0342 min^{-1}); 73 % removal efficiency of BCG within 20 min; 90 % removal efficiency of 4-nitrophenol within 90 min (k = 0.02373 min^{-1}); 85 % removal efficiency of DCP within 120 min (k = 0.015 min^{-1})	3	[173]
$[Ag(bbi)][\{Ag(bbi)\}_4\{Ag_3(V^V_4O_{12})_2\}]\cdot 2H_2O$; bbi = 1,1'-(1,4-butanediyl)bis(imidazole)	octavanadate	MB	[MB] = 10 ppm; amount of catalyst = 150 mg; light source = 125 W Hg lamp; MB = methylene blue	70 % within 90 min	5	[174]
$\{(H_2O)_2[Cu_8(\mu_4\text{-}OH)_6Cu_6(H_2O)_6(cpt)_{12}](SiW^{VI}_{12}O_{40})_3(EtOH)_4(H_2O)_7\}$; Hcpt = 4-(4'-carboxyphenyl)-1,2,4-triazole	Keggin	MB, RhB	[dye] = 10^{-5} M; amount of catalyst = 20 mg; light source = Xe lamp; MB = methylene blue; RhB = rhodamine B	94.3 % removal efficiency of MB within 50 min; 85.4 % removal efficiency of RhB within 70 min	nsp	[175]
$H_3PMo^{VI}_{12}O_{40}$@MOG-Cr; MOG-Cr = metal-organic gel	Keggin	MB, RhB, MO	[dye] = 10 ppm; amount of catalyst = 10 mg; light source = 50 W Xe lamp; MB = methylene blue; RhB = rhodamine B; MO = methyl orange	99 % removal efficiency of MB within 60 min; 97 % removal efficiency of RhB within 60 min and 91 % removal efficiency of MO within 120 min	3	[176]
$Fe\text{-}PW^{VI}_{12}O_{40}/TiO_2$	Keggin	BPA	[BPA] = 50 ppm; amount of catalyst = 50 mg; BPA = bisphenol A	100 % within 24 min	4	[177]
$H_3PW^{VI}_{12}O_{40}/TiO_2$	Keggin	CR, MO, PG, OII, EB, AS, MB, NR, RhB, FA	[dye] = 50 ppm; amount of catalyst = 250 mg; light source = 400 W Xe lamp; CR = Congo red; MO = methyl orange; PG = Ponceau G; OII = orange II; EB = eriochrome blue black B; AS = alizarin S; MB = methylene blue; NR = neutral red;	92 % removal efficiency of CR within 120 min; 72.4 % removal efficiency of MO within 240 min; 94.8 % removal efficiency of PG within 180 min; 67.2 % removal efficiency of OII within 240 min; 75.8 % removal efficiency of EB within 180 min; 72.8 % removal efficiency of AS within 240 min;	nsp	[178]

				96 % removal efficiency of MB within 60 min; 98.2 % removal efficiency of NR within 60 min; 98 % removal efficiency of RhB within 60 min; 75 % removal efficiency of FA within 240 min		
$[Cu_2(CPBPY)_4(H_2O)_2][PW^{VI}_{12}O_{40}][OH]\cdot 6H_2O$; CPBY = *N*-(3-carboxyphenyl)-4,4′-bipyridinium	Keggin	MB	[MB] = 10 ppm; amount of catalyst = 50 mg; pH = 6.3; light source = 300 W Xe lamp; MB = methylene blue	98.2 % within 60 min under visible light and 97.7 % within 60 min under NIR light	nsp	[179]
$(NH_4)_5[\{PW^{VI}_{11}O_{39}\}Mn^{II}(H_2O)]$ (**1**) $(NH_4)_5[\{PW^{VI}_{11}O_{39}\}Fe^{II}(H_2O)]$ (**2**) $(NH_4)_5[\{PW^{VI}_{11}O_{39}\}Co^{II}(H_2O)]$ (**3**) $(NH_4)_3[PW^{VI}_{12}O_{40}]$ (**4**) $(NH_4)_5[\{PW^{VI}_{11}O_{39}\}Ni^{II}(H_2O)]$ (**5**) $(NH_4)_5[\{PW^{VI}_{11}O_{39}\}Cu^{II}(H_2O)]$ (**6**) $(NH_4)_5[\{PW^{VI}_{11}O_{39}\}Zn(H_2O)]$ (**7**)	Lacunary Keggin	MG	[MG] = 10 μM; amount of catalyst = 24 mg; pH = 5.77; light source = 500 W Xe lamp; in the presence of O_2; MG = malachite green	< 80 % removal efficiency of MG for (**1**), (**2**), (**3**), (**4**); > 80 % removal efficiency of MG for (**5**), (**6**), (**7**) within 30 min	5	[180]
SiW_{12} (**1**), $SiW_{11}V$ (**2**), $SiW_{10}V_2$ (**3**), SiW_9V_3 (**4**) PW_{12} (**5**), $PW_{11}V$ (**6**), $PW_{10}V_2$ (**7**), PW_9V_3 (**8**); $SiW_{12} = [\alpha\text{-}SiW^{VI}_{12}O_{40}]^{4-}$, $SiW_{11}V = [\alpha\text{-}SiV^{V}W^{VI}_{11}O_{40}]^{5-}$, $SiW_{10}V_2 = [\alpha\text{-}SiV^{V}_2W^{VI}_{10}O_{40}]^{6-}$, $SiW_9V_3 = [\alpha\text{-}SiV^{V}_3W^{VI}_9O_{40}]^{7-}$, $PW_{12} = [PW^{VI}_{12}O_{40}]^{4-}$, $PW_{11}V = [PV^{V}W^{VI}_{11}O_{40}]^{4-}$, $PW_{10}V_2 = [PV^{V}_2W^{VI}_{10}O_{40}]^{5-}$, $PW_9V_3 = [PV^{V}_3W^{VI}_9O_{40}]^{6-}$	Keggin	atrazine, chlorpyrifos, dieldrin	[pesticides] = 100 ppm; light source = 100 W Hg lamp	> 80 % removal efficiency of atrazine for (**1**); < 40 % removal efficiency of atrazine for (**4**) within 90 min; < 60 % removal efficiency of atrazine for (**5**); < 30 % removal efficiency of atrazine for (**8**) within 90 min; > 70 % removal efficiency of chlorpyrifos for (**1**); < 40 % removal efficiency of chlorpyrifos for (**4**) within 120 min; > 45 % removal efficiency of chlorpyrifos for (**5**); < 25 % removal efficiency of chlorpyrifos for (**8**) within 120 min; > 40 % removal efficiency of dieldrin for (**1**); < 30 % removal efficiency of dieldrin for (**4**) within 120 min; > 40 % removal efficiency of dieldrin for (**5**); < 20 % removal efficiency of Dieldrin for (**8**) within 120 min	nsp	[181]
$W^{VI}_{10}O_{32}^{4-}$	decatungstate	NAD	[NAD] = 3×10^{-4} M; amount of catalyst = 3×10^{-4} M; light source = 1000 W Xe lamp with a monochromator (λ = 365); NAD = 2-(1-naphthyl)acetamide	100 % within 22 h	nsp	[182]
APS-functionalized $TiO_2/CoPW^{VI}_{11}$ (**1**) APS-functionalized $TiO_2/NiPW^{VI}_{11}$ (**2**); APS = 3-aminopropyltriethoxysilane, $CoPW^{VI}_{11} = K_5[Co^{III}(H_2O)PW^{VI}_{11}O_{39}]$, $NiPW^{VI}_{11} = K_5[Ni^{II}(H_2O)PW^{VI}_{11}O_{39}]$	Keggin	CR, MO, AS, NR, HCB	[dye] = 50 ppm; [pesticide] = 2 ppm; amount of catalyst = 100 mg; light source = 125 W Hg lamp; CR = Congo red; MO = methyl orange; AS = alizarin S; NR = neutral red; HCB = hexachlorobenzene	94 % removal efficiency of CR for (**1**) and 93 % for (**2**) within 60 min; 98 % removal efficiency of MO for (**1**) and 95 % for (**2**) within 30 min; 94 % removal efficiency of NR for (**1**) and 90 % for (**2**) within 40 min; 89% removal efficiency of AS for (**1**) and 83 % for (**2**) within 240 min; 99.4 % removal efficiency of HCB for (**1**) and 97.8 % for (**2**) within	nsp	[183]

				60 min		
$[Fe(phen)_3]_2[SiW^{VI}_{12}O_{40}]\cdot 3$ DMF; phen = 1,10-phenanthroline, DMF = *N*,*N*-dimethylformamide	Keggin	DCP	[DCP] = 10 ppm; amount of catalyst = 300 ppm; light source = 400 W Hg lamp; DCP = 2,4-dichlorophenol	100 % within 60 h	5	[184]
$(H_2bimb)[Cu^{II}(bimb)][SiW^{VI}_{12}O_{40}]\cdot 2H_2O$ (**1**) $(H_2bimb)_2[Co^{II}(H_2O)_3(bimb)][SiW^{VI}_{11}Co^{II}O_{39}]\cdot 6H_2O$ (**2**) $KH[Cu^{II}(bimb)]_2[SiW^{VI}_{11}Co^{II}O_{39}]\cdot(H_2O)]\cdot 2H_2O$ (**3**) $[Cu^{II}(bimb)]_4[GeW^{VI}_{12}O_{40}]\cdot H_2O$ (**4**); bimb = 1,4-bis(1-imidazolyl)benzene;	Keggin	MB	[MB] = 10 ppm; amount of catalyst = 50 mg; light source = 125 W Hg lamp; MB = methylene blue	89.5 % removal efficiency for (**1**); 87.5 % removal efficiency for (**2**); 90.4 % removal efficiency for (**3**); 84.7 % removal efficiency for (**4**) within 90 min	nsp	[185]
$H_3PW^{VI}_{12}O_{40}/SiO_2$ (**1**); $H_4SiW^{VI}_{12}O_{40}/SiO_2$ (**2**)	Keggin	HCH, PCNB	[pesticides] = 6.5 ppm; amount of catalyst = 250 ppm for 1 and 350 ppm for 2; light source = 125 W Hg lamp; HCH = hexachlorocyclohexane; PCNB = pentachloroe????nitrobenzene	95 % removal efficiency of HCH for (**1**) and 75 % for (**2**) within 4 h; 100 % removal efficiency of PCNB for (**2**) within 50 min	8	[186]
PW^{VI}_{12} (**1**) SiW^{VI}_{12} (**2**) GeW^{VI}_{12} (**3**); $XW_{12} = [X^{n+}W^{VI}_{12}O_{40}]^{(8-n)-}$ (X^{n+} = P^{5+}, Si^{4+}, Ge^{4+})	Keggin	X-3B	[X-3B] = 6.37×10^{-5} M; amount of catalyst = 50 mg; pH = 1; X-3B = reactive brilliant red	k = 0.0004 min^{-1} for (**1**); k = 0.0037 min^{-1} for (**2**); k = 0.001 min^{-1} for (**3**)	nsp	[187]
PW_{12}/TiO_2; $PW_{12} = [PW^{VI}_{12}O_{40}]^{3-}$	Keggin	DEP, DMP, DBP	[dye] = 5 ppm; amount of catalyst = 100 mg; light source = 300 W Xe lamp; DEP = diethyl phthalate; DMP = dimethyl phthalate; DBP = di-*n*-butyl phthalate	84 % removal efficiency of DEP; 80 % removal efficiency of DMP; 98 % removal efficiency of DBP within 90 min	nsp	[188]
TEOS/PW_{12} (**1**) TEOS/SiW_{12} (**2**); TEOS = tetraethoxysilane, $PW_{12} = [PW^{VI}_{12}O_{40}]^{3-}$, $SiW_{12} = [SiW^{VI}_{12}O_{40}]^{4-}$	Keggin	MB, RhB	[dye] = 2.975×10^{-5} M; amount of catalyst = 75 mg; light source = 100 W Hg lamp; MB = methylene blue; RhB = rhodamine B	100 % removal efficiency of MB for (**1**) within 5 min; 89 % removal efficiency of RhB for (**1**) and 89 % for (**2**) within 5 min	nsp	[189]
TiO_2/PW_{12}; $PW_{12} = [PW^{VI}_{12}O_{40}]^{3-}$	Keggin	MO	[MO] = 10 ppm; pH = 2; light source = 300 W Hg lamp; MO = methyl orange	93.2 %	nsp	[190]
$[SiW^{VI}_{12}O_{40}]^{4-}$/rGO; rGO = reduced graphene oxide	Keggin	MB, RhB	[dye] = 35 ppm; $NaBH_4$ = 0.05 M; amount of catalyst = 0.5 mL; MB = methylene blue; RhB = rhodamine B	reduction reactions completed in 34 min for MB and in 81 min for RhB	-	[191]
phenyl/amine Janus silica/ $PW^{VI}_{12}O_{40}^{3-}$	Keggin	MO	[MO] = 50 ppm; v[H_2O_2] = 10 µL; MO = methyl orange	99.2 % within 3 h	6	[192]
$H_3PW^{VI}_{12}O_{40}$/*N*-decyl-*N*'-carboxymethyl imidazolium bromide	Keggin	MO	[MO] = 1.2 mM; amount of catalyst = 3.0 mL; pH = 3-6.5; MO = methyl orange	Highly efficient degradation of MO without light irradiation in the presence of H_2O_2	6−8	[193]
$(NH_4)_3PMo^{VI}_{12}O_{40}$	Keggin	MB	[MB] = 10^{-5} M; amount of catalyst = 125 mg; pH = 5; MB = methylene blue	94.6 %	16	[194]
GO-$H_3PW^{VI}_{12}O_{40}$-triethylenetetramine; GO = graphene oxide	Keggin	MB	[MB] = 25 ppm; amount of catalyst = 25 mg; light source = sunlight; MB = methylene blue	84 % within 150 min	5	[195]
POMOF/wood filter; POM = $H_3PMo^{VI}_{12}O_{40}$, MOF = UiO-66, MOF = metal-organic framework	Keggin	MB, GV	[dye] = 8 ppm; MB = methylene blue; GV = gentian violet	96.63 %; 97.41 %	3	[196]
$(Et_4N)_4[V^{V}Mo^{VI}_{12}O_{40}]\cdot MeCN$; MeCN = CH_3CN	Keggin	AB10B, MB	[dye] = 5 ppm; amount of catalyst = 3 mg for AB10B and 2 mg for MB; H_2O_2 30 % (2.0 mmol); AB10B = amido black 10B; MB = methylene blue	99 % removal efficiency within 45 min for AB10B; 99 % removal efficiency within 20 min for MB	3	[197]
$H_6P_2Mo^{VI}_{15}W^{VI}_3O_{62}$ @MIL-96(Al); MIL-96(Al) = Al-based metal-organic framework	Wells-Dawson	MB	[MB] = 40 ppm; amount of catalyst = 10 mg; pH = 4; MB = methylene blue	92.4 % removal within 5 min	5	[198]
SPT-T-G; SPT = $Na_6[H_2W^{VI}_{12}O_{40}]$,	Polytungs	AO	[AO] = 15 ppm; amount of catalyst = 40 mg; pH = 5;	100 % within 110 min	nsp	[199]

T = $C_4H_6O_6$, G = $C_5H_9NO_4$			AO = auramine-O			
$[Cu^{II}_2(ipbp)_2(H_2O)_2][Cu^{II}W^{VI}_{12}O_{40}]\cdot 3H_2O$ (**1**) $[Co^{II}_2(H_2ipbp)_3(H_2O)_2(Co^{II}O_6)_2]$ $[SiW^{VI}_{12}O_{40}]\cdot H_2O$ (**2**); $H_2ipbp\cdot Cl$ = 1-(3,5-dicarboxyphenyl)-4,4'-bipyridinium	Keggin	MB, RhB	[dye] = 0.02 mM/L; amount of catalyst = 25 mg; under visible light; MB = methylene blue; RhB = rhodamine B	complete degradation within 40 min for MB and 180 min for RhB by **1**; complete degradation within 50 min for MB and 60 min for RhB by **2**	4-6	[200]
$(Et_3NH)_5[PMo^{V}_6Mo^{VI}_6O_{40}(V^{V}O)_2]$	Keggin	MB, CV, RhB	[dye] = 100 mg/L; amount of catalyst = 300, 140, and 80 mg for MB, CV, and RhB; MB = methylene blue; CV = crystal violet; RhB = rhodamine B	99.7 %, 99.8 %, 99.7 % flocculation efficiency for MB, CV, and RhB within 5 min	5	[201]
$[SiW^{VI}_9V^{V}_3O_{40}]^{7-}$@MIL-101(Cr); MIL-101(Cr) = Cr-based metal-organic framework	Keggin	MB, RhB	[dye] = 10 mg/L; amount of catalyst = 30 mg; MB = methylene blue; RhB = rhodamine B	98 % removal efficiency within 12 min for MB and 18 min for RhB	3	[202]
$[PW^{VI}_{12}O_{40}]^{3-}$@ZIF67 (**1**) $[PM^{VI}o_{12}O_{40}]^{3-}$@ZIF-67 (**2**) ZIF-67 = Co-based metal-organic framework	Keggin	*E. coli* *S. aureus*	[sample] = 1 mg/ml	84.6% antibacterial efficacy against *E. coli* and 98.8% against *S. aureus* for (**1**) and 69.2% antibacterial efficacy against *E. coli* and 97.8% against *S. aureus* for (**2**)	nsp	[203]
$[Co(L)(V^{V}_4O_{12})_{0.5}(H_2O)]\cdot 2H_2O$ L = N,N'-bis(3-methylpyridin-3-yl)-2,6-naphthalenediamide	$[V_4O_{12}]^{4-}$ cluster	phenol, 2-CP, *m*-cresol	[phenolic compounds] = 400 mg/L; amount of catalyst = 10 mg; under visible light; $n(H_2O_2)/(phenol)$ = 46; 2-CP = 2-chlorophenol	94%, 92.9%, 92.6% degradation efficiency for phenol, 2-chlorophenol and m-cresol within 140 min	4	[204]
FeTCPP-PW^{VI}_{12} (**1**) FeTCPP-PMo^{VI}_{12} (**2**) H_4TCPP = tetrakis(4-carboxyphenyl) porphyrin	Keggin	phenol	[phenol] = 400 mg/L; amount of catalyst = 20 mg; light source = 300 W Xe lamp; H_2O_2 = 3ml (30%)	100% degradation efficiency within 20 min for (**1**) and 10 min for (**2**)	5	[205]
Pd-PTA-MIL-100(Fe) Pd = Palladium nanoparticle PTA = PW^{VI}_{12} MIL-100(Fe) = Iron-based metal-organic framework	Keggin	theophylline, IBP	[pollutant] = 20 mg/L; T = 30 °C; amount of catalyst = 5 mg; pH = 6; H_2O_2 = 40 µL; light source = 300 W Xe lamp; IBP = ibuprofen	99% degradation efficiency for theophylline and ~ 50% for ibuprofen within 90 min	4	[206]
PMV-TiO_2/Ag PMV = $[PMo^{VI}_{10}V^{V}_2O_{40}]^{5-}$ Ag = Silver nanoparticle	Keggin	2,4-DFP 2,4-DCP 2,4-DBP HFBPA TC Cr(VI) MO	[DHP] = 10 ppm; [HFBPA] = 10 ppm; [TC] = 20 ppm; [Cr(VI)] = 80 ppm; [MO] = 20 ppm; T = 10 °C; amount of catalyst = 20 mg; light source = 300 W Xe lamp DHP = dihalophenol; HFBPA = hexafluorobisphenol; TC = tetracycline; Cr(VI) = $K_2Cr_2O_7$; MO = methyl orange	100% degradation efficiency for 2,4-DFP within 120 min; 100% degradation efficiency for 2,4-DCP within 180 min; 100% degradation efficiency for 2,4-DBP within 210 min; 100% degradation efficiency for HFBPA within 210 min; 90% degradation efficiency for TC within 80 min; 100% reduction efficiency for Cr(VI) within 30 min; 100% degradation efficiency for MO within 30 min;	4	[207]

*nsp- not specified by authors

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