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Hydroxyl-assisted selective epoxidation of perillyl alcohol with hydrogen peroxide by vanadium-substituted phosphotungstic acid hinged on imidazolyl activated carbon

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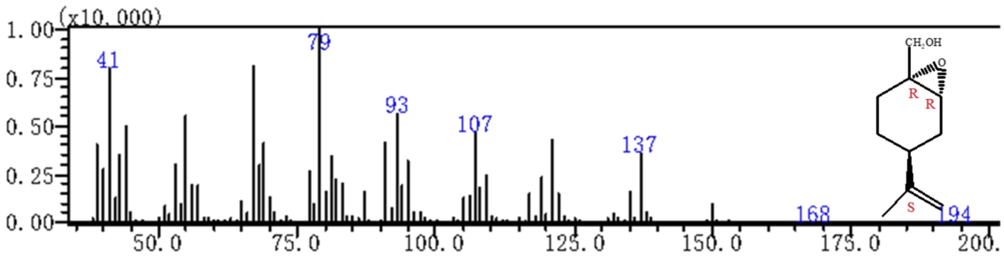


Fig. S1. GC-MS of cis-1,2-epoxide

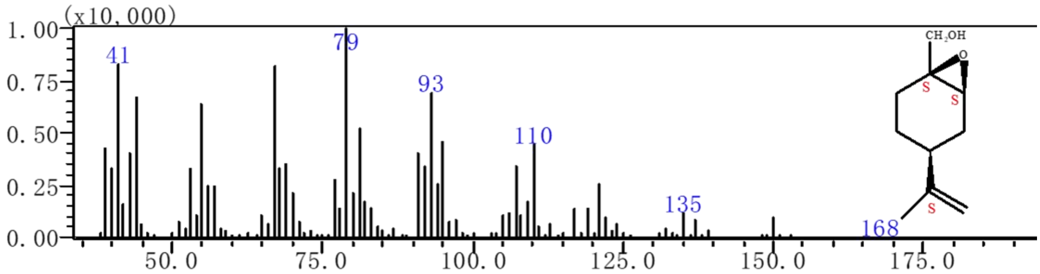


Fig. S2. GC-MS of trans-1,2-epoxide

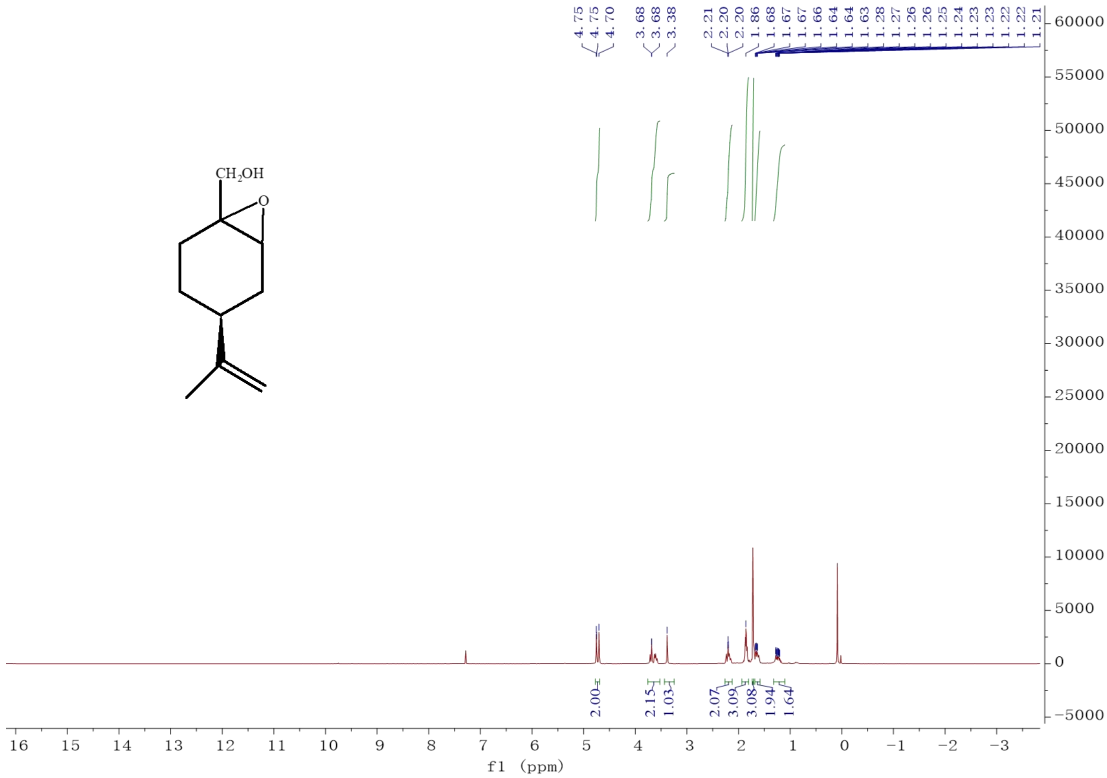


Fig. S3. ^{1}H NMR of 1,2-epoxide diastereomeric mixture

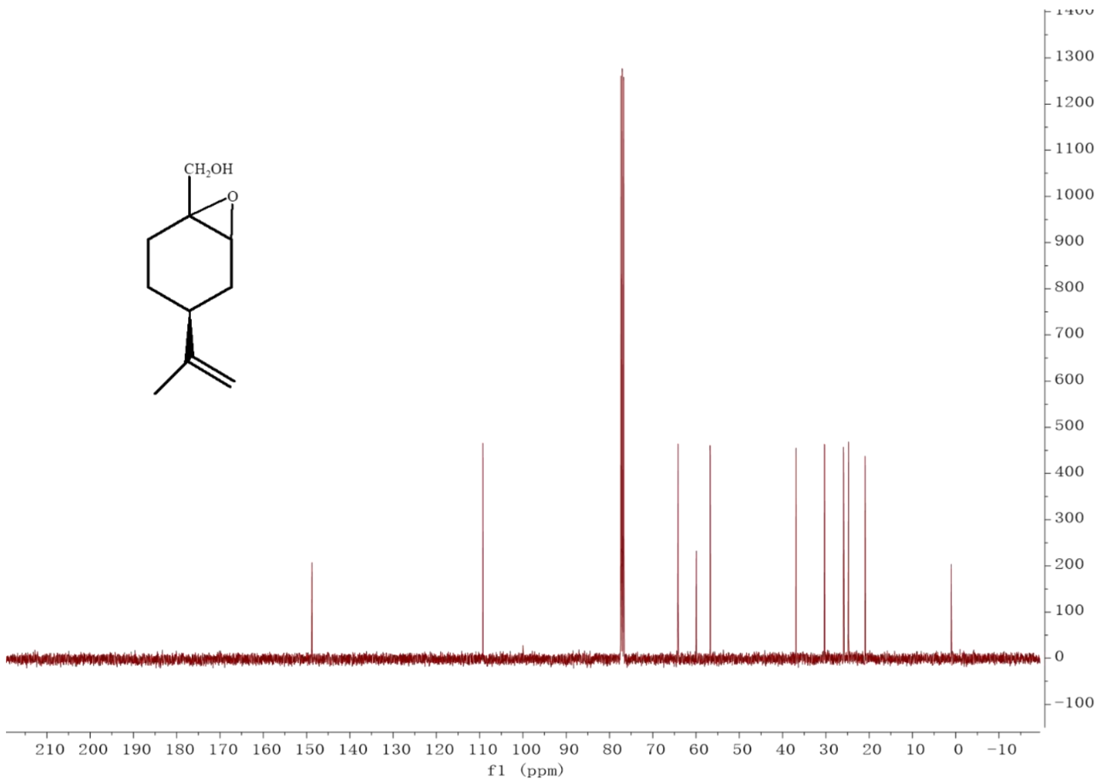
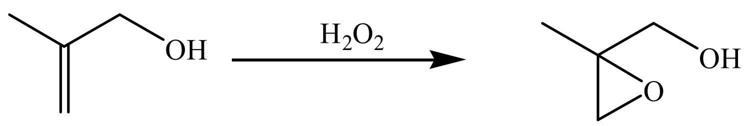


Fig. S4. ^{13}C NMR of 1,2-epoxide diastereomeric mixture

Table S1. Catalytic oxidation of methallyl alcohol by AC-COIMIH$^+$[$H_4PW_{10}V_2$]$^-$



Entry	$n(H_2O_2)$ (mmol)	Conv. (%)	Sel. (%)	
			t=4.399	Epoxy methallyl alcohol
1	1.5	21.0	8.2	91.8
2	3	39.0	14.1	85.9

Reaction condition:1 mmol substrate, 4 mL CH_3CN, 13 *wt*.% of catalyst, 60 ℃, 5 h.

Table S2. The oxidation reaction of limonene under different reaction conditions.

Entry	$n(H_2O_2)$ (mol)	Time(h)	Conv. (%)	Sel. (%)					
				1	2	3	4	5	?
1	1.5	5	5.7	34.5	18.0	21.9	-	15.1	10.5
2	3	12	37.8	20.4	39.4	11.9	3.9	5.2	19.2

Reaction condition:1 mmol limonene, 4 mL CH_3CN, 13 *wt*.% of catalyst, 60 ℃.

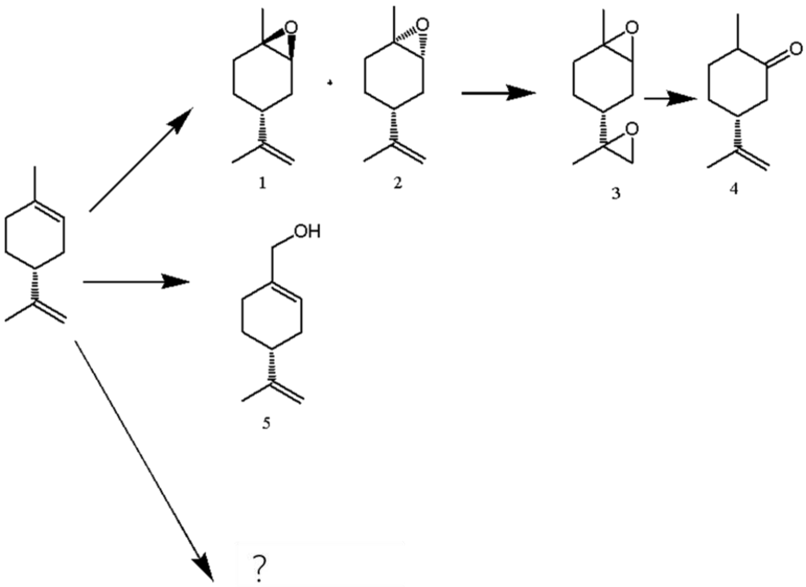


Fig. S5. Distribution of Limonene Oxidation Products

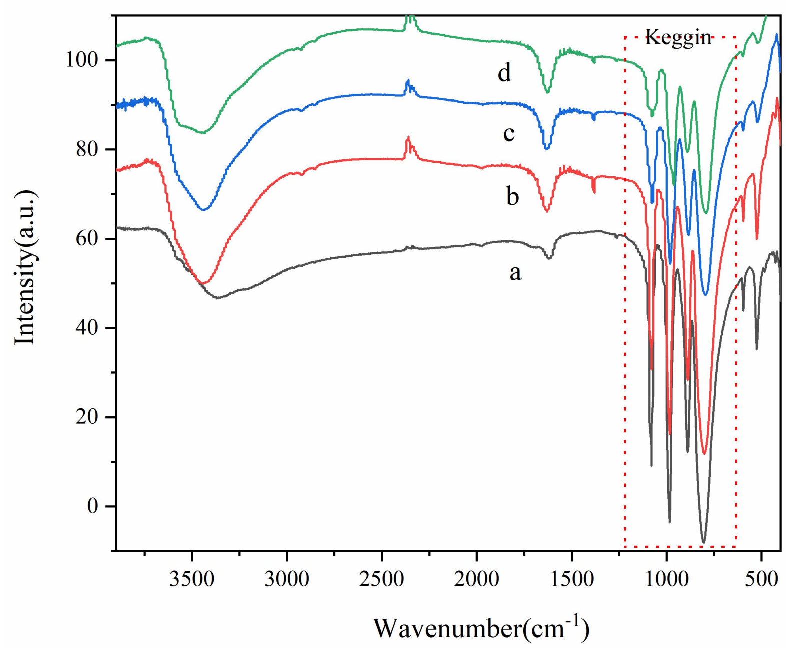


Fig. S6. FT-IR of (a) $H_3PW_{12}O_{40}$, (b) $H_4PW_{11}VO_{40}$, (c) $H_5PW_{10}V_2O_{40}$ (d) $H_6PW_9V_3O_{40}$

Table S3. Infrared data of vanadium substituted Keggin POMs

Vibration method	Wavenumber（cm^{-1}）			
	$H_3PW_{12}O_{40}$	$H_4PW_{11}VO_{40}$	$H_5PW_{10}V_2O_{40}$	$H_6PW_9V_3O_{40}$
δ(H-OH)	3409	3440	3438	3448
ν(O-H)	1626	1626	1624	1623
ν(P-Oa)	1081	1081	1080	1079
ν(M=Od)	984	983	983	982
ν(M-Ob-M)	892	887	885	885
ν(M-Oc-M)	806	804	797	794

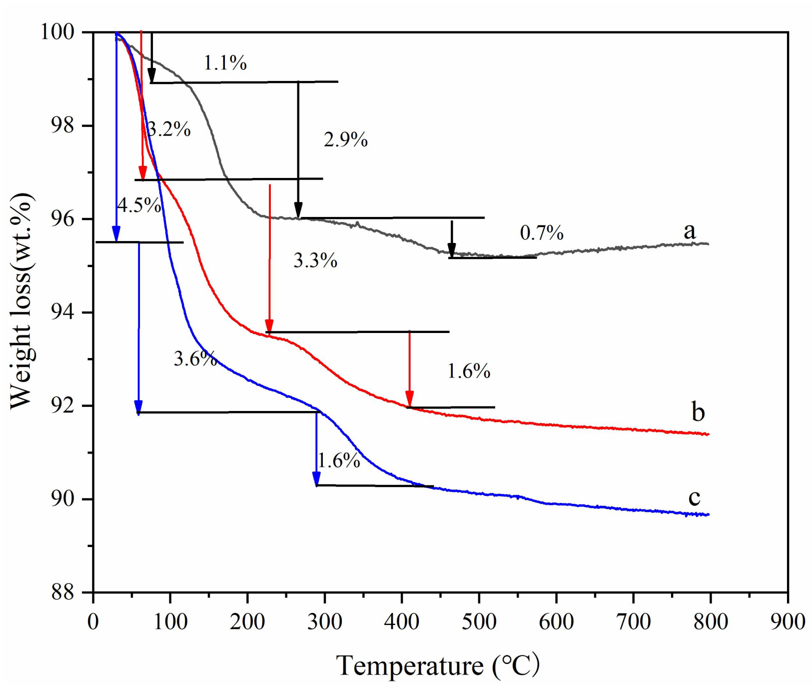


Fig. S7. TG of (a) $H_4PW_{11}VO_{40}$, (b) $H_5PW_{10}V_2O_{40}$, (c) $H_6PW_9V_3O_{40}$

Table S4 ICP results of vanadium substituted Keggin POMs.

Heteropolyacids	W (*wt.*%)		V (*wt.*%)	
	Theoretical value	Test value	Theoretical value	Test value
$H_4PW_{11}VO_{40}\cdot 4H_2O$	71.70	71.35	1.81	1.75
$H_5PW_{10}V_2O_{40}\cdot 5H_2O$	67.93	67.33	3.76	3.47
$H_6PW_9V_3O_{40}\cdot 5H_2O$	64.27	64.16	5.94	5.62